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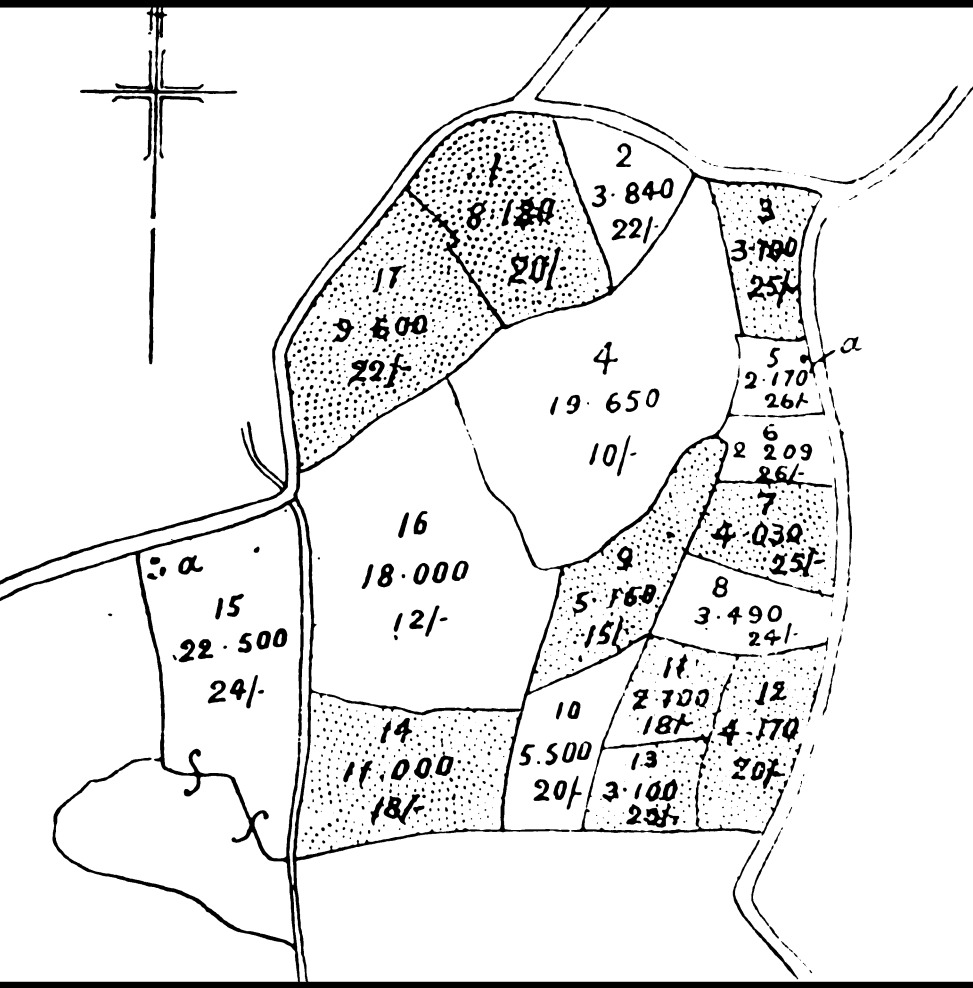

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Institution of Civil Engineers of Ireland

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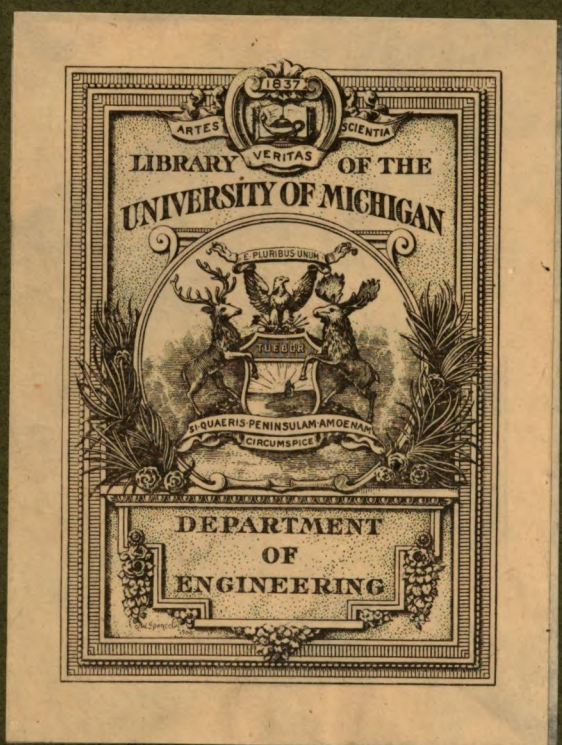

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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

IRELAND.

SEVENTIETH SESSION, NOV., 1903, TO MAY, 1904.

VOL. XXXI.

DUBLIN:
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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[*4th November*, 1903.]

Mr. JOHN H. RYAN, President, in the Chair.

THE PRESIDENT read the reply from His Majesty the King to the Address which the Council, on behalf of the Institution, presented to him on the occasion of his visit to Dublin in July, 1903.

The Address read as follows:—

TO HIS MOST GRACIOUS MAJESTY EDWARD THE SEVENTH, KING OF GREAT BRITAIN AND IRELAND AND OF THE BRITISH DOMINIONS BEYOND THE SEAS, AND EMPEROR OF INDIA.

MAY IT PLEASE YOUR MAJESTY—

We, the President, Council, and Members of the Institution of Civil Engineers of Ireland, incorporated by Royal Charter, offer to Your Majesty, and to Your Royal

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Consort, Queen Alexandra, a loyal and cordial welcome to Dublin.

Knowing the great interest displayed at all times by Your Majesty in the progress of Engineering works in all parts of Your Majesty's Empire, we can point with pride to the fact that Members of the Institution of Civil Engineers of Ireland have contributed in no small degree to the accomplishment of such works, not only in this country, but throughout your Majesty's dominions.

We tender to Your Majesty the expression of our continued loyal attachment to Your Person and Throne, and pray that you may be long spared to rule over this mighty Empire.

[Here follow the signatures of the President and Council.]

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THE CASTLE,
DUBLIN, 31*st July*, 1903.

SIR,

His Excellency the Lord Lieutenant has been commanded by the King to forward you herewith a copy of His Majesty's gracious reply to the Address of your body.

I am, sir, your obedient servant,

PLUNKET.

J. H. RYAN, Esq., President,
Institution of Civil Engineers of Ireland.

HIS MAJESTY'S JOINT REPLY TO THE ADDRESSES.

LADIES AND GENTLEMEN,

I accept with sincere gratification your loyal assurances of devotion to my throne and person, and I thank you for hearty greetings which you tender to the Queen and myself on our first visit to Ireland since my accession.

I rejoice to hear of a newly-awakened spirit of hope and enterprise among my Irish people, which is full of promise for the future. It will be a source of profound happiness if my reign should be coincident with a new era of social peace and of industrial and commercial progress in every part of Ireland.

I regret my inability to make an individual acknowledgment to each of the bodies that have taken part in this demonstration of goodwill to myself and my family, but I recognise that the manifold activities of Irish life are very fully represented here.

I ask you to accept from the Queen and from myself an assurance of deep sympathy with you and with your fellow-workers in the cause of religion and philanthropy, of art and science, of industry and commerce, as well as in the important work of Local Government. I pray that the Divine Blessing may rest abundantly on your varied labours for the benefit of the community, and for the elevation of the national life.

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The reading of the King's reply was received with applause.

The following Medals and Premium awarded by the Council were presented :—

Mullins' Gold Medal to W. E. Lilly, Member, for his paper, "The Design of Plate Girders."

Mullins' Silver Medals to—

Joseph Tatlow, Associate, for his paper, "Irish Railways, their Progress and Development during the Last Decade of the Last Century."

W. E. Lilly, Member, for his paper, "The Strengths of the Materials of Construction."

J. T. Trevor Dillon, Associate Member, for his paper, "Some Notes on Route-surveys with the Plane Table in Egypt."

R. G. Allanson-Winn, Member, for his paper, "Foreshore Protection at Youghal, and Deep-sea Erosion on the East Coast of England."

The Chaloner Smith Premium of Books to H. Norman Leask, Associate Member, for his paper, "The Destruction of Towns' Refuse, and some of the Principles involved in the Construction of Refuse Destructors."

The thanks of the Council were accorded to F. W. Higginbotham, Associate, for his paper, "Refrigeration."

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[*4th November*, 1903.]

MR. JOHN H. RYAN, President, in the Chair.

The following Candidates were balloted for and duly elected :—

JAMES F. BLANCHARD, GEORGE ALEX. NICOLLS and GEORGE LAWRENCE JOYNT, as Associate Members; and CHARLES J. QUIRK, as Associate.

The following paper was read :—

REMARKS ON SOME EXAMINATIONS, COMPETITIVE AND QUALIFYING, AS AVENUES OF EMPLOYMENT FOR ENGINEERS.

By ROBERT COCHRANE, I.S.O., Vice-President of the Institution of Civil Engineers of Ireland.

THE subject of examinations as a means of testing knowledge is one which is now occupying considerable attention in connection with the teaching of science and technical education. It may not be amiss to devote a short time to a consideration of the higher and professional class of examinations regarded as avenues to the employment of young engineers in the public service.

An examination of the syllabus of one of the technical schools, designed to meet the wants of the operative class, discloses a curriculum in many points not inferior to that of a professional school. In this connection it may be considered whether the standard of knowledge aimed at for young engineers is of a nature best adapted to meet the exigencies of their subsequent employment.

A good deal has been written about the education of the engineer; the subject has lately been revived, and it engaged the attention of the British Association at its annual meeting last year, but nothing particularly useful resulted from the conference. The question would form an interesting paper in itself, and would seem to deserve better treatment at the hands of educational experts than it has yet received. It is, however, desired to give a practical rather than an academical

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tendency to the present paper, and, if possible, to make it of use to younger members in indicating a class of appointments in the public service easily within their reach.

Employment for engineers is found in two spheres—viz., the Public Services and Private Practice. The former may be subdivided into two sections, including—1st, Those situations obtained by interest or selection, and 2nd, those which are obtained by passing a competitive or qualifying examination. The latter class of situation only will be dealt with in this paper.

Before proceeding to remark on the various branches of the public service in which the assistance of men possessing professional knowledge is required, it may be permitted to me to notice briefly and retrospectively one of the principal appointments in that class—viz., that of County Surveyor in Ireland—which is peculiar in some respects, inasmuch as it now comes under the head of both the first and second subdivisions before mentioned. Since the making of appointments to this office was transferred to the County Council by the Act of 1898, that body can select any name out of the list of those who have passed a qualifying examination ; formerly the candidate was appointed whose name stood highest in the list.

The advantages which accrued indirectly to the engineering profession through this examination in keeping up a high standard of professional education can hardly be over-estimated. In Ireland, which is backward in some ways, there are frequent instances of initiative taken greatly in advance of other countries. As an illustration, in the appointment of County Surveyors there is the first recorded instance of a scheme of examination for electing engineers to a position of importance.

The post of County Surveyor was established by Act of Parliament in the year 1833. That Act provided for the

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appointment of a Board of Examiners to inquire into the knowledge and qualifications of candidates. It is noteworthy that this examination was prescribed some 22 years before examinations for appointments to the Civil Service were instituted. The profession of civil engineer at that time was at a very low ebb in Ireland, indeed it could hardly be said to exist as we know it now. This Institution had not yet been established, and the construction and erection of works of magnitude—roads, bridges, and canals—were then frequently in the hands of persons without education or skill.

The examination papers which were drawn up at this period (1833) consisted of questions in architecture or building, road making and surveying, and were of a comparatively high standard, and of a class that could with advantage be used at the present day for these subjects. The examination was qualifying, and all who attained a certain standard were certified as eligible for employment and were appointed to counties until the list was exhausted, when a new examination was held. The demand for suitable candidates caused a run on certain offices in which young men had opportunities to train for county surveyorships, for which a fee of £300 for each pupil was usually charged.

One of our Past-Presidents pointed out in his Address that this Institution, founded in 1835, "owed its origin partly to the want felt by the large body of County Surveyors of Ireland and of engineers employed then in many important public works." *

These examinations and the demand for suitable men, together with the general impetus given in 1840 to the introduction of railways in Ireland, and the efforts of individual members of the Institution, combined to press

* See Vol. VIII. Transactions of the Institution of Civil Engineers of Ireland, page 49. Address by Robert Mallet, F.R.S., President. In the first published List of Members of the Institution, in 1849, there were 33 County Surveyors out of a total of 104 Members and Associates.

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home the increasing want of better means of education, not only in engineering, but in physical science generally, and led ultimately to the formation of a School of Engineering in Trinity College, Dublin, in 1841–2, and to the establishment of Professorships of Engineering in the three Queen's Colleges at Belfast, Cork, and Galway, in connection with the Queen's University in Ireland, founded in 1845. Diplomas or licences were given to students, and afterwards degrees in engineering to those who had successfully passed through the schools. Similar chairs had not been provided in any of the English universities until after the foundation of the school in Trinity College; but schools had been established in England by private individuals as commercial speculations, and a department of engineering was attached to King's College, London.* The Royal College of Science in Dublin, established later, also contains a department in engineering and gives a Diploma of Associate to those who have completed their studies and passed the examinations.

The facilities for obtaining degrees in engineering in Ireland, and the comparative absence of such facilities in England,† have affected both the Institutions of Civil Engineers, but with different results. The Diploma of Membership of the English body is looked on as the hall-mark of the professional engineer, while in Ireland there is, or, rather, has been, a tendency to regard as sufficient the holding of the diploma or degree in one of the numerous schools of engineering, and to stop there without qualifying

* The date of its constitution as a School of the University of London is the date of the Act—1898—when the University was re-organised. The Engineering School, however, had been in existence from 1839, a few years after the foundation of the College.

† In the Universities of St. Andrews N. B., Glasgow, Edinburgh, Durham, Wales, London, and the Victoria University degrees are given as B.Sc. (Engineering), and in Cambridge University, the degree of B.A. (Mechanical Sciences Tripos). Certificates in Engineering are given in several other schools and colleges, but without University distinction.

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for the Diploma of Membership of the Institution. This state of things, however, is rapidly disappearing, as the value of membership, not only as a guarantee of professional training, but also of professional experience, is becoming better known. At the present time about 25 per cent. of the Members and Associates of this Institution have university degrees. In the English Institution the corresponding proportion is only 10 per cent., of which about one-third are degrees obtained in the Irish universities.

Having briefly glanced at the important part played by the earlier examinations for County Surveyorships in assisting the foundation of Engineering Schools in Ireland we will return to the later development of these examinations.

Under the provisions of the 25th & 26th Vict., c. 106, commonly called the County Surveyors (Ireland) Act, 1862, the examination of candidates for the situation of County Surveyors devolved on the Civil Service Commissioners.

Before that date, and since 1833, as already shown, examinations for County Surveyors were held under the Grand Jury Act, 6 & 7 William IV., c. 116; clause 39 of which enacted—

"That the Lord Lieutenant of Ireland shall from time to time appoint a Board of three Civil or Military Engineers to act, without salary or emolument, in Dublin, who shall from time to time examine into and certify the qualifications of all persons desirous to act as surveyors or assistant surveyors under this Act, and such Lord Lieutenant shall appoint from time to time out of such persons so certified one or more surveyor or surveyors to act at the salary or salaries hereinafter provided for each county, and it shall be lawful for said Lord Lieutenant from time to time at his pleasure to remove such surveyors from county to county."

In 1844 a separate Grand Jury Act was passed for County Dublin (7 & 8 Vict., c. 106), which enabled that county to be divided into districts, with a surveyor for each.

The subjects of examination for County Surveyor under

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the Grand Jury Act were confined to practical papers in road construction and maintenance, bridge building, surveying and levelling, also architecture, including the construction of prisons, hospitals, and courthouses. The salary attached to the post of County Surveyor under the Grand Jury Act was limited to £300 per annum and £50 for an office, and the pay of their assistants was £50 per annum.

The Act 24 & 25 Vict., c. 63, commonly called "The County Surveyors, &c. (Ireland), Act, 1861," provided for increased remuneration to County Surveyors by classifying the different counties, and fixing the maximum salary for a first class county at £600, second class at £500, and third class at £400 per annum; the limit of the salary of an Assistant Surveyor was raised to £80 per annum.

By the Act passed in the following year, 25 & 26 Vict., c. 106 (1862), section 39 of the Act 6 & 7 William IV., and section 7 of 7 & 8 Vict., c. 106, were repealed, which provided for the examination of County Surveyors and their Assistants by a Board of Civil or Military Engineers, and it was enacted instead that the qualification of persons desirous to act as Surveyors—

"Shall be examined into and certified by the Civil Service Commissioners for the time being appointed by Her Majesty in Council; and whenever a vacancy shall occur in any of such offices, an examination shall be held of all persons desirous to fill the same at such time in Dublin as the said Commissioners shall appoint, of which examination due notice shall be given, and one of the persons who shall be certified by the said Commissioners shall be appointed to the vacant office of Surveyor by the Lord Lieutenant or other Chief Governor or Governors of Ireland, subject to the approval of the Grand Jury of such counties."

The persons who had been already examined and certified under the former Act were eligible for appointment without urther examination.

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The County Surveyors Superannuation (Ireland) Act was passed in 1875.

Although the appointment to the post of County Surveyor was subject to an examination by the Civil Service Commissioners, candidates for the post of Assistant to a County Surveyor continued to be examined by the Board of Civil or Military Engineers as before. On the introduction of the Local Government (Ireland) Act, 1898, a further improvement was made in the position of the Assistants; in many counties the salaries have been increased by the County Council and approved of by the Local Government Board. Regulations have been framed by that Board for a qualifying examination for candidates for this office (See Appendix A), and it is gratifying to observe that under Article 2 (*b*) of these Regulations an Associate Member of this Institution shall be deemed qualified for the position of Assistant County Surveyor without further examination. These posts are sought after by junior men; though the remuneration is not excessive, the time spent in the situation counts towards qualifying in practical experience for admission to the examination for a County Surveyor.

When the County Surveyors (Ireland) Act, 1862, became law, there were still on the list the names of a number of men who had passed the old examination. The practice under the former Act had been to hold periodical examinations, and all who passed were entitled to a certificate of competency to fill the post. This list was not exhausted until the year 1869, when a vacancy was caused in the County of Westmeath. While preparing the present scheme of examination the Civil Service Commissioners were in communication with the Under Secretary for Ireland, and some members of the County Surveyors' organisation, by whose exertions the Act of 1861 had been passed, made suggestions in formulating a schedule of examination. As the former mode of examination had

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given satisfactory results in obtaining suitable men, and importance was attached to experience rather than to mere scholastic attainments, it was suggested to place the superior limit of age at 45 or 50, but the age was eventually placed at from 26 to 40 years.

With the view of giving due value to the practical training and experience of candidates it was arranged that the examination should be divided into two parts, and that Part I., which may be termed the theoretical portion, should have a maximum of only 340 out of a total of 1,000 marks, or little over one-third of the whole examination, and that a candidate showing "some proficiency under one, at least, of the heads included in Part I. would be eligible to proceed to Part II. of the examination."

The successful men, however, were those who took all the theoretical subjects. As an illustration, in the examination of 16th June, 1874, the first competitor obtained 592 marks out of 1,000, of which 293 were in the theoretical part; the second got 491, of which 155 marks were in Part I. This left the first candidate at 299 marks for the practical part (II.), and the second candidate at 336. In the examination of 11th July, 1882, the first candidate obtained 677 marks out of 1,000, the second 676. The first obtained 205 in the theoretical part and the second obtained 155, which gave the successful man a total of 472 marks in practical engineering against 521 obtained by the unsuccessful candidate.

The character of the examination for County Surveyors which, taken as a whole and as a competitive examination, is probably all that could be desired, and has tended to elevate the standard of professional attainments in this country, but it is not so satisfactory when regarded only as a qualifying examination. Under the Act of 1862 an examination was held for each vacancy, and the candidate who stood highest on the list was nominated for the post. At present, if a

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candidate be selected by a County Council who has not already passed the examination it becomes necessary to obtain the certificates of the Civil Service Commissioners before the Local Government Board will sanction his appointment. An examination is then held, and the appointment may be given to any man on the list—the lowest instead of the highest—provided he shows the amount of knowledge necessary to satisfy the examiners, and, as has already been indicated, this may be very much lower than the standard attained under the examination when the highest on the list was selected.

In further consideration of the improvement in the professional status of engineers in Ireland which has accrued from these competitive examinations it is worthy of note that when the first vacancies occurred in 1869, eight years after the Act had been passed making the appointments competitive, the successful competitiors were not Irishmen. Irish engineers, though they had eight years to think of it, were not so well equipped by professional education that they could take advantage of the prizes offered, but as soon as they became aware of their shortcomings in this respect they remedied them and took the first places in most of the later examinations.*

Revised rules for the examination and selection of County Surveyors, rendered necessary by the Act of 1898, were

* In the first examination, which was held 2nd November, 1869, for two vacancies, the first places were taken by English engineers. The marks obtained were 515 for the first place, and 475 for the second, out of 1,000. For this examination 35 were examined and 24 qualified. It is remarkable that the second successful candidate got no marks in either mathematics or geology. The next examination was held 8th November, 1870, for one vacancy; 14 were examined and 9 qualified. The highest place was taken by an Irishman, a graduate of the Engineering School of Trinity College, and a member of this Institution, who gained 696 marks out of 1,000, which was a considerable increase on the marks gained at the former examination. The next examination was held in December, 1871, when still higher marks were attained to, reaching to 739. A high standard has been kept up at all the later examinations. The men who take all the theoretical subjects score highest.

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drawn up by the Local Government Board in August, 1899 (see Appendix A). An examination under these rules was held in 1903 for a vacancy in County Wicklow, which resulted in the appointment of one of our members to the vacant post.

The subjects of examination are as undernoted, and copies of recent examination papers will be found in the Appendix :—

COUNTY SURVEYOR (IRELAND).

(Including District Surveyor for the County of Dublin.)

Limits of Age, 26 to 40.

Part I.	Max. marks
Mathematics, including Geometry, Trigonometry, Algebra, Differential and Integral Calculus, and Geometrical Optics	100
Mechanical Philosophy, including Statics and Dynamics, Hydrostatics and Hydraulics, Pneumatics, and Heat regarded as a source of Power	100
Experimental Science, including Inorganic Chemistry, Heat, Electricity, and Magnetism	100
Geology and Mineralogy	40
Part II.	
Strength and other Properties of Materials, and the Calculation of Stresses and Strains	100
(A) Railway and Canal Engineering	140
(B) Marine Engineering, including Harbour, Dock, Sea, and Reclamation Works	140
(C) Hydraulic Engineering, including Water Supply, Sewage, and Irrigation	140
(D) County Works, including Architecture, Roads, Drainage, and River Works	140
	1,000

*** Each of the groups lettered (A), (B), (C), (D) to include Designs, Estimates, Specifications, and the mechanical contrivances connected with it. *Candidates must pass in one subject in Part I.*,

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and must attain such a standard of proficiency in Parts I. and II. combined as shall satisfy the Civil Service Commissioners.

Before proceeding to notice the appointments open in Government departments, a short notice of the history and gradual development of the principle of open competition for such situations, and the rules regulating same, as now adopted in the public service, may be considered appropriate.

The principle of competitive examinations as applied to the selection of candidates for appointments in the public service was first adopted in 1855 by an Order in Council dated 21st of May of that year, which provided that "before being admitted to probation" a certificate of qualification should be obtained from the Civil Service Commissioners, who would examine as to the following particulars :—

"1st. To ascertain that the candidate is within the limits of age prescribed in the department to which he desires to be admitted ;

"2nd. To ascertain that the candidate is free from any physical defect or disease which would be likely to interfere with the proper discharge of his duties ;

"3rd. To ascertain that the character of the candidate is such as to qualify him for public employment ; and

"4th. To ascertain that the candidate possesses the requisite knowledge and ability for the proper discharge of his official duties."

It was also ordered that the rules applicable to each department should be settled in consultation with that department, and the regulations under which the candidates are examined have been prescribed by those authorities.

Independent of but following upon the granting of a certificate of qualification after examination, provision was made for a period of probation, and it was ordered that after the candidate had received his certificate—

"He shall enter on a period of probation, during which his

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conduct and capacity in the transaction of business shall be subjected to such tests as may be determined by the chief of the department for which he is intended; and he shall not be finally appointed to the public service, unless upon satisfactory proof of his fitness being furnished to the chief of the department after six months' probation."

This probationery period is a great safeguard against unsatisfactory appointments, and must be considered as an integral and valuable portion of the system of selection by competitive examination.

The "competitive principle" was introduced gradually—some doubt having been expressed in certain quarters as to the wisdom of its general application—and at first it was confined to minor appointments. The principle was affirmed in a resolution of the House of Commons dated 24th April, 1856, and in the following year another resolution was agreed to "in favour of the adoption of the principle of competition as a condition of entrance to the Civil Service, and that the application of that principle ought to be extended."

In the year 1860 a Select Committee of the House of Commons was appointed to consider the subject, and after taking evidence as to the result of the system declared "strongly in favour of open competition," and that even in situations of the superior class it should be universally applied.

In 1868 during the thirteen years which had elapsed since the introduction of the system 50,861 candidates had been examined for home service, and 28,596 certificates had been issued to the successful competitors.

Attached to the Order in Council, dated 4th June, 1870, are two Schedules—A. and B., the former containing a list of all the departments to which the principle of open competition was to be applied. Schedule B. is a list of the situations of a special or temporary character to which the principle was not to apply. These Schedules are subject to change

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from time to time. When notice is given that a situation is transferred to Schedule A. it is to be understood that the appointment thereto can only be made after open competitive examination.

This order placed nearly all public departments employing professional men in Schedule A., and except as after noted no appointments were afterwards made until after examination in such professional and scholastic subjects as have been prescribed by the Civil Service Commissioners and the heads of the departments in which the vacancies arose. While extending the principle practically over all situations in the Service, this Order in Council contains a special reservation in Clause VII., which, as it affects professional appointments, may be considered sufficiently important to quote at length. It is as follows :—

Clause VII.—"In case the chief of a department to which a situation belongs and the Lords of the Treasury shall consider that the qualifications in respect of knowledge and ability deemed requisite for such situation are wholly or in part professional or otherwise peculiar, and not ordinarily to be acquired in the Civil Service, and the said chief of the department shall propose to appoint thereto a person who has acquired such qualifications in other pursuits, or in case the said chief of the department and the Lords of the Treasury shall consider that, either for the purpose of facilitating transfers from the Redundant List or for other reason, it would be for the public interest that examinations should be wholly or partially dispensed with, the Civil Service Commissioners may dispense with the examination, wholly or partially, and may grant their certificate of qualification upon evidence satisfactory to them that the said person possesses the requisite knowledge and ability, and is duly qualified in respect of age, health and character."

One of the more important professional posts in Ireland placed in Schedule A. of the Order in Council of 4th June,

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1870, is that of Assistant Engineer to the Board of Public Works, which carries with it advancement to the rank of Chief Engineer without further examination. The scheme for this was formulated in 1874, and is a most comprehensive schedule, embracing 14 subjects, the examination in which extended over a fortnight. A feature in it is that failure in any one of the subjects is fatal to the eligibility of the candidate. At an examination in 1874 there were 17 competitors, and the first in the list was an English engineer (who had previously been successful in a competition for a County Surveyorship in June, 1872); 3,563 marks were obtained out of a maximum of 4,850.

A second examination was held in 1887 for the same post, the marks gained in which amounted to 4,420 out of 5,600, and on this occasion also, Irish engineers were not successful in the open competition. With this experience it is not surprising to find in another public department in Ireland, where the professional situations are not yet brought under Schedule A., and appointments thereto are made by selection, that in the process of selection the result has been the same as in the open competition, and an engineer not educated in Ireland has been successful.

A similar result followed the holding of a local competitive examination for the situation of Engineer for the City of Cork.

All these appointments have been found to be most satisfactory, and possibly no better selections could have been made, and as a set off we have the numerous appointments in Great Britain and abroad filled with distinction by Irish engineers.

It has, however, been considered desirable to revise the schedule of the examination for the post of Assistant Engineer to the Board of Works, and in future it is proposed that it shall be a limited competition amongst a number of candidates to be in the first instance nominated by the Board. For the next

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vacancy the subjects of examination will be as in the Appendix. Candidates must pass in all the subjects enumerated; they should have spent at least five years as Engineer or Resident Engineer on works of magnitude. The Board will select and nominate men of proper preliminary training, and suitable in respect of education and physique, for the post before admission to the competitive examination. The original scheme for the post was as follows :—

"The examination will be in the following subjects, viz. :—

1. Handwriting.
2. Orthography.
3. English Composition.
4. Arithmetic (including Vulgar and Decimal Fractions).
5. Algebra to Quadratic Equations.
6. Geometry.
7. Plane Trigonometry.
8. Hydrostatics, Hydrodynamics, and Hydraulics.
9. Levelling and Surveying, including the adjustment of the instruments and the plotting the Surveys and Sections.
10. Drawing, including the preparation of working drawings in detail.
11. Taking out quantities, and preparing estimates and specifications from drawings.
12. The various machines used in engineering works, and the working of them.
13. Knowledge of the qualities, uses, modes of testing, and strength of materials.
14. Engineering works, including the construction of roads, railways, canals, harbours, docks, piers, and breakwaters; drainage of marsh lands, reclamation from the sea, and drainage and water supply of towns.

"Candidates failing, in any of the above subjects will not be eligible.

"Candidates will be required to show what preliminary training

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they have undergone to qualify them for the situation, and that they have been employed for at least five years in the capacity of Engineer or of Resident Engineer on works of magnitude."

It has been a subject of some concern to the authorities of the different departments that in the majority of cases there is a dearth of suitable candidates, As an instance of this, in the situation of Assistant Surveyor in the Office of Public Works, with a commencing salary of £200, rising by increments to £500, with prospect of further promotion, at a recent open competitive examination, though the papers were reduced to much simplicity, the Civil Service Commissioners could not grant their certificate to any of the candidates competing, and, in consequence, three situations had to be filled up under Clause VII, of the Order in Council of 4th June, 1870, already referred to.

This examination for Assistant Surveyor was first framed in 1874, when there were two vacancies, but only one candidate obtained a certificate; the standard of examination, though high, was not by any means too high for the importance of the office. The particulars of it as it originally stood are as follows :—

"The examination will be in the following subjects, viz. :—

1. Handwriting.
2. Orthography.
3. English Composition.
4. Arithmetic (to Vulgar and Decimal Fractions).
5. Algebra (to Simple Equations).
6. Elementary Geometry.
7. Geometrical Drawing.
8. Freehand Sketching in outline.
9. Theory of Construction.
10. Knowledge of the qualities, uses, modes of testing, and strength of materials.
11. Designs and Specifications and Estimates for Buildings.
12. Taking out quantities, measuring, and valuing.

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13. Surveying and levelling.
14. Sanitary Science, including air, water, gas, daylight, ventilation, sewage, &c.

"Candidates failing in any of the above subjects will not be eligible.

"Candidates must possess the practical experience necessary to qualify them for a situation of this nature. They must have been employed for at least five years in the superintendence of buildings, and will be required to produce satisfactory proof of their efficiency and practical knowledge."

In this case also it has been found desirable to amend the subjects of examination, and to make the competition a limited one; candidates will be selected by the Board in the first instance as suitable in respect of education, training and physique.

The particulars of the future examinations for vacancies in this post will be found in the Appendix.

In the Irish Valuation Office there is a large professional staff which is recruited from candidates for the post of Valuer and Surveyor (second section). In 1900 an open competitive examination was held for 3 vacancies, for which there were 5 applicants, 4 of whom withdrew during the examination, and only one was examined and certified. Owing to the failure of open competition in obtaining suitable men, the 2 other vacancies had to be filled up under Clause VII. of the Order in Council of 4th June, 1870. (*See* 45th Report, Civil Service Commission, Appendix, pp. 23 and 27.)

In this department also it has been found necessary to limit the competition to those who may be nominated by the Commissioner of Valuation, to whom I am indebted for a copy of the special regulations under which the last examination for four vacancies was conducted. Candidates are required to state what technical education and practical training they have undergone to qualify themselves for a

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situation of this nature, and must show that they have served for at least two years under a Civil Engineer or Surveyor in good general practice, and that they have been engaged in a responsible position during the greater part of that time in the carrying out of important surveys.

A copy of the examination papers used at a limited competition this year will be found in the Appendix.

It is hoped by the Commissioner of Valuation that for these situations the principle of open competition will be reverted to for future appointments. In view of the proposed revaluation of Ireland the number of professional appointments on this staff will be largely increased. In recent years a considerable increase has been made in the professional staff of the office.

In the year 1901 there was a vacancy in the Irish Land Commission for a situation as surveyor and draughtsman, and an open competitive examination was held, at which three candidates presented themselves. It was found that none of them had the requisite technical training or could pass the examination, consequently no certificate was issued.* A similar breakdown occurred in 1899, when at one of the examinations there was found no eligible candidate sufficiently qualified for surveyor and draughtsman in the same office. Contrast this with the result of an examination for the situation of draughtsman in the Patent Office, where in 1901 there were 17 competitors, 7 of whom qualified. In the competition for clerk and draughtsman in the office of the Surveyor-General, Prison Department, England, there were 11 competitors, of whom 9 qualified for one vacancy.

The foregoing examples may be taken as affording fairly conclusive evidence that while there is not a lack of candidates anxious to obtain these appointments they do not always appear to be sufficiently equipped to pass the neces-

* See 46th Report, Civil Service Commission, Appendix, pp. 12 and 26.

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sary examinations. We are therefore driven to the conclusion that the standard of professional knowledge aimed at by the younger members of the profession is capable of some improvement. The knowledge that is required to pass these examinations is not so much that which is to be acquired in the class-room or from books as that which is to be gained in the office or on works in progress, but it must also be admitted that a special course of preparation is frequently necessary for success in an examination.

During the past year examinations have been held for vacancies in the Valuation Office and in the Board of Works Office, under the revised regulations before referred to. The departments concerned advertised the posts very fully,* with the result that hundreds of applications were received, and the difficulty was in making a preliminary selection for the Civil Service Commissioners' test examination. The vacancies were all satisfactorily filled up after examination. The inference to be drawn from this raises a doubt as to whether the limited and rather cryptic notices given by the Civil Service Commissioners in a few papers provide adequate publicity of the vacancies and forthcoming competitions.

When the death of a County Surveyor causes a vacancy nearly every engineer in Ireland knows of it, and candidates are in readiness. There is little doubt that if other vacancies had sufficient publicity there would be better competition for the appointments.

The inference likely to be drawn, at first sight, from the comparative breakdown of the principles of open competition, as applied to professional appointments in Ireland, is that there are not candidates sufficiently qualified to pass the necessary examinations. The most obvious inferences are not always the most correct, and in the present case we must

* Heretofore publication of the notices of the vacancy had been left to the Civil Service Commissioners.

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look for another contributory cause. In the case of County Surveyors' examinations, and in the two limited competitions for the Board of Works and the Valuation Office, all held this year, there was no lack of candidates, because there was much greater publicity given than in the cases wherein the breakdown occurred.

For the Home and Indian Civil Services there is no lack of candidates, because, in addition to the vacancies being numerous, the examinations occur at regular intervals, and due preparation can be made, but for the situations directly under consideration the vacancies are few and occur at irregular intervals; besides, the candidates are drawn from the ranks of men already engaged in the pursuit of their profession. Such facts operate adversely to procuring a sufficient number of competitors.

The remedy seems to lie in having these posts and the method of filling them brought prominently under the notice of intending competitors, and also in increased study by young engineers, and if the preparation of this paper assists in this direction its object will have been attained.

It would be an advantage if the different examinations could, as far as practicable, be assimilated, so that if a candidate misses one office he may have a chance for another, and that, instead of preparing for only one, he may have the whole range of professional situations in his eye as affording a possible field of employment. This co-ordination of schemes has to some extent been adopted, but its further extension is desirable.

In addition to those in Irish Departments it may be desirable to mention that other professional appointments are open to engineers, such as those in the Department of the Director of Works in the Admiralty, and in the New Military Works Department of the War Office, &c.

It will be observed that in all these departments the appoint-

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ments open to competition are the junior posts, from which, however, promotion to the higher and better paid situations are made.

War Department—Civil Staff.—The staff for engineering services is divided into two—viz., permanent and temporary.*

The permanent staff consists of one Chief Surveyor, at a salary of £800 to £1,000; 8 First-class Surveyors, at £400 to £500; 18 Second-class, at £200 to £375; and 40 Assistant Surveyors, at £180 to £280, all of whom are liable for service abroad in the Crown Colonies. About one-half of the Assistant Surveyors are always abroad, and they then receive extra pay, which varies at different stations.

The staff is recruited by entrance to the class of Assistant Surveyors by means of competitive examinations, which are only held as vacancies occur. There are at present about 6 vacancies, which are filled up temporarily.

It is highly probable that a much larger Civil Staff will be employed in the future, as a result of the Departmental Inquiry held recently under the chairmanship of Lord Esher. Several important changes have been suggested by this Committee, the result of which would be to entrust the carrying out of all large works to a professional Civil Staff instead of to the Royal Engineers.

The morning papers of the 19th October contained an announcement that Colonel Lawson, R.E., had been appointed Director-General of the New Military Works Department

* In the Civil Staff of the Royal Engineers' Department there are a large number of men employed on what is called the temporary staff—viz., Quantity Surveyors at £7 per week; Surveyors' Clerks, £1 15s. to £3 10s.; Clerks of Works, £2 12s. to £3 15s.; Draughtsmen, £1 15s. to £3 10s.

Appointments to the temporary staff are made as vacancies occur, application to be made to the local Royal Engineer Officer accompanied by testimonials. These men are engaged on large works, such as the defensive coaling stations, erection of new barracks and alterations of old, and at the standing camps at the Curragh, Aldershot, Salisbury Plain, &c. No examination is required beyond producing satisfactory testimonials and passing a short probationary period.

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just formed. The issue of the warrant for the formation of the new Civil Staff may be expected soon.

This staff will probably be formed on the lines of the Civil Engineer Staff in the Department of the Director of Engineering and Architectural Works at the Admiralty, particulars of which are now given.

Admiralty—Department of the Director of Works.—The staff of this Department, as recently re-organised, consists of 2 Assistant Directors of Works, salary £850 to £1,000; 11 Superintending Civil Engineers, £600 to £700; 12 Civil Engineers, £400 to £500; 22 Assistant Civil Engineers (1st Grade), £300 to £400; 21 Assistant Civil Engineers (2nd Grade), £180 to £300.

The staff is recruited by entrance to the 2nd Grade of Assistant Civil Engineers, from which the other ranks are filled by promotion. Full particulars of this examination will be found in the Appendix C.

There is another important class of professional situations in the Admiralty Works Department, composed as follows:—

One Chief Surveyor, salary £800 to £1.000;

Six Surveyors, £400 to £500, and

Nineteen Assistant Surveyors at £250 to £350 1st Grade, and £150 to £250 2nd Grade.

This Staff is recruited by entrance after examination to the grade of Assistant Surveyor, from which promotions to the higher grades are made. See Appendix for subjects of examination, &c.

Particulars of the other departments will be found in the Appendix. See also the Civil Service Estimates for the year 1903-4.

It has been suggested that it would be of value to give specimens of typical examination papers, and with the approval of the Council these are now attached in the Appendix to this paper. Permission for their publication has been obtained

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from the Comptroller of His Majesty's Stationery Office, in whom the copyright is vested, and thanks are due to him for his courtesy in allowing them to be here reproduced.

It is extremely desirable that young engineers should acquaint themselves with the form of such examination papers, by the study of which they can test their knowledge of the different subjects. This should prove useful in many ways, quite apart from the prospect of candidature for any of the examinations. In view of the recent adoption of a qualifying examination, the passing of which is a condition precedent to election by the Institution of Civil Engineers (of London) and the possibility of similar action by this Institution, it is useful to have before us adopted tests of professional education, which may be alike useful in framing examinations and in enabling candidates, by a course of study, to prepare for them.

It may be observed that as most of the more important professional posts filled by competition, or subject to a qualifying examination, are only open to candidates having a certain number of years' experience of the requisite character in more or less responsible positions, the effect of the specified requirements is of a two-fold character. On the one hand, the prospective employers of the candidate are safe-guarded against the chance of his having little more than a theoretical training; while on the other hand the too prevalent tendency of young men engaged on works—not only to neglect the continuous self-improvement in scientific knowledge which every engineer owes to his profession and to himself, but even to forget the systematic or theoretical training which he received at school or college—must be checked in the case of any young engineer who strives to obtain a professional appointment dependent on examination. Here the influence of competitive examination in raising the true standard of professional training is seen, and

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is most valuable, as in every branch of the engineering profession a competent knowledge of principles as well as the practice is absolutely necessary in order to command any permanent success, and to enable the engineers in the United Kingdom to keep abreast of their professional brethren in other countries.

THE PRESIDENT (Mr. J. H. Ryan) said he was sure they would all join with him in according a very hearty vote of thanks to the author for the most admirable paper with which he had favoured them that evening. It affected many of their junior members—those who would come after them—and also opened up an avenue of employment for junior engineers.

The paper was a most important one, and offered a large field for discussion, in which he hoped they would all join.

The question of the education of an engineer, be he civil, mechanical, or electrical, was of course of paramount importance. There was no doubt in these days that a thorough education was necessary for engineers in all branches of the profession. In this direction engineering schools in Ireland, he was sure, were alive to the fact. It was important that engineers should have a thorough technical and practical education. The author had touched upon that in the concluding part of his paper. Of course the practical knowledge of the profession could only be acquired in an engineering office.

He hoped they would all join in a vote of thanks to the author for the admirable paper he had given them.

MR. GLOVER said he thought the meeting must be of unanimous opinion that this evening's paper was a most useful one. It should have good effects in two ways:—(1) In showing important prospects of employment open to engineers; and (2) in pointing out the necessity of proper training if

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the young Irish engineer was to hold his own against outsiders. As regards the latter, he believed that a fair knowledge of pure and mixed sciences was necessary for any man who hoped to succeed as an engineer. In the past the same necessity did not exist so largely as at present; while in the future the necessity would become greater and greater. On the other hand, theory and book knowledge without experience were practically useless. It was like learning music through the eye and from books without the murmur of a vibration to reach the ear. It was possible for a pure theorist who might not know by sound one note from another to examine in music; yet, on the other hand, a good performer on an instrument might not know by name one note from another. This performer, like the purely practical man, may meet village requirements and meet them well; but he need not be playing to a village audience if underlying his knowledge gained from experience there was a substantial foundation of scientific training. Both should co-exist like the concave and convex sides of a curve.

Like nearly everyone else, engineers were face to face with competition, and those who neglected an opportunity of being properly equipped must take the consequences. And let it not be thought that in "private practice" there were no examiners. One's clients would soon come to a verdict as certainly as the Civil Service Commissioners would.

The avenues of employment with which Mr. Cochrane dealt are in the public service, but he took no notice of those obtainable by patronage. His (Mr. Glover's) advice to young engineers would be to act on the same principle, relying on merit and fitness, and if a patron, or one having interest, turned up by-and-by the matter could be reconsidered.

The paper dealt with appointments obtainable by passing either a competitive or a qualifying examination. For many reasons all examinations should be competitive, but probably

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the Legislature was afraid to entirely eliminate patronage and favour, especially in local appointments.

To their young members the list of appointments Mr. Cochrane gave must be very useful, and even older members would be glad to have ready to hand up-to-date information as affecting the profession.

Mr. Cochrane evidently thought that this Institution should try to help their members in obtaining employment, just as well as to improve them by other classes of papers to be better engineers. It was an excellent idea. And might one not go farther? Why should not there be a register kept here for engineers wanting engineers, and for engineers wanting work? It is a corollary from the paper, and if any man could work the corollary our Vice-President was the man. For his part he would ask him to consider the matter. And talking of getting work for our young men, he found that under the new Land Act the Estate Commissioners would require an affidavit from a competent surveyor stating that he visited the lands and examined the map upon the ground; that the several holdings proposed to be sold are correctly marked on the said map, and that the schedule of areas is correct. Connection with this Institution would no doubt settle the question of what "competent" means.

The paper was almost entirely a paper of facts, and it was hard to criticise anything in it.

As to the dearth of suitable candidates for certain posts, to which Mr. Cochrane referred, he was disposed to think that the salaries and duties of the posts would not tempt suitable men to come forward. He had no doubt if the salaries were increased much of the "dearth" would disappear. But he did agree that they should have young men amongst them not only able but willing to compete for every class of appointments.

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Within the last thirty years Ireland had improved very much from an engineer's point of view, not only in making appointments by examination, but in the demand for engineers generally. The standard of living for the mass of their countrymen was gradually being raised. Every day they read in the newspapers about housing their artisans, their labourers and their very poor. Sanitary work of all kinds was being agitated for, and so also for river and land drainage; water supplies—even canals and roads—were now criticised, which did for years without complaint. In his early days things were not as they were now, and a paper like the one they were discussing would not be possible. He begged to second the vote of thanks to Mr. Cochrane. There was no member who took a greater interest in their affairs than Mr. Cochrane. They must congratulate him too in being one of those who, a few months ago, received high honours from His Majesty the King for efficient work in the public service.

Mr. F. J. Dick said that the paper, with its appendices, should be of immense value to the younger members of the profession, containing, as it does, a mass of information which is not readily accessible elsewhere.

The principle of qualifying examinations seems an excellent one, and should assure a certain indispensable knowledge of scientific data. The question really is to what point in a given case such a pass examination should be carried? It may be observed that even in the cases where the examinations have been strictly competitive they were really qualifying examinations. Enquiries were always made locally as to the character and experience of the successful candidate, who had also to pass a strict medical examination, and his appointment was a probationary one for at least six months. If the purely competitive system were abolished, and qualifying examinations up to a certain standard substituted, there need be no fear that unsuitable men will be appointed if,

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as a matter of ordinary business, care be taken by the local authority, or other public body, to obtain the best professional advice from engineers of acknowledged standing and integrity, unconnected with any of the candidates or their relatives. Without such advice, of course, the risk of an unsuitable selection being made would remain.

The need for qualifying examinations in all branches of our profession becomes occasionally apparent. Sometimes there are engineers in charge of works (even if in subordinate positions) who are nevertheless ignorant of the most elementary principles of engineering, and such ignorance is often sought to be excused by the assertion that they are what is called "practical men." This is an old controversy, perhaps best answered by the preliminary dissertation in Rankine's treatise on Applied Mechanics :—"If in the solution of certain problems some have recourse to what is known as 'rule of thumb,' whilst others resort to formulæ whose *rationale*, or even reliability, they have no means of checking, the resulting state of matters is neither a guarantee of the adequacy of public works for the purposes designed, nor does it conduce to their economical construction."

Any process which will tend to eliminate from responsible public posts men of insufficient scientific knowledge of their profession should, in these times of international emulation, be heartily welcomed.

Mr. P. C. Cowan said the paper was one of great interest. The author had collected a large amount of valuable information, and had put it before them in a very clear and complete way.

It was regrettable that since the passing of the Local Government (Ireland) Act, 1898, the candidate for a County Surveyorship who obtains the first place in the examination, which is conducted on the same lines as before, has not necessarily any better chance of appointment than other candidates

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who qualify with lower marks, as the votes of the County Councillors, with whom the appointment lies, have to be secured. If the present conditions had existed in 1885 he would probably never have had his pleasant experience as a County Surveyor in Ireland, which lasted for thirteen years, and was almost certainly all the happier because he owed it entirely to a competitive examination.

Under the Act already mentioned the Local Government Board had to decide what increase in salary should be given to officers who held the positions before the passing of the Act, on account of any increased duties due to the change in the law, where the existing officers and the County Councils did not agree on the subject, and a circular was issued indicating the approximate amount of increased salaries which the Board considered equitable. It is gratifying that the scale suggested was adopted in many counties, and that in some of them more liberal terms were adopted by the County Councils. The rates of salary for all new appointments to county officers are now, however, entirely at the discretion of the new councils.

The examinations for Assistant County Surveyors, now conducted by the Local Government Board, are of an elementary character, and as the position requires little special skill, but chiefly probity, intelligence and industry, there is no lack of candidates, but with very few exceptions the percentage of full marks obtained was low, though the papers are easy.

It might be useful to note that the certificates issued by the Local Government Board, in connection with these examinations, cannot be considered as anything more than evidence that the Board has been satisfied that the persons named therein are qualified to undertake the simple, though important, duties of an Assistant to a County Surveyor. The certificates are in no way evidence of qualifications for general engineering

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or architectural work, though some Assistant Surveyors are highly qualified and very capable men.

It is much to be regretted that no provisions exist in the Statutes to prevent incompetent persons from acting as engineers or architects, and a large waste of public money is due to the want of such provisions. He thought it most desirable in every proper interest, and especially in that of the ratepayers, that the law should be amended so that all public works should be designed and supervised by persons possessing at least such minimum qualifications as should be prescribed by the central authority sanctioning the works or expenditure. The matter might usefully engage the attention of the Institution, and might be much more easily dealt with than the wider question of the registration of civil engineers or architects. It would evidently be a great step in advance if a more efficient and economical expenditure of public funds on works were ensured, though some private individuals might continue, as at present, to consider the services of all professing engineers and architects as equal in value, and to employ those practitioners who ask least for their services, without consideration of the large percentages which are commonly saved or wasted by good or bad design and supervision. Almost any intelligent person with slight training can build in a wasteful way a small house or a simple bridge, but true professional skill is required for the production of the best results in the most economical way in the simplest structure.

Mr. Price said that, as might have been expected from Mr. Cochrane, and he was sure that the meeting would agree, a very valuable paper had been provided. With reference to the difficulty experienced by the Council in inducing members to contribute papers for reading and discussion, he suggested that one cause which deterred members from reading papers was that the experience of those who had

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devoted time and thought to the preparation of suitable papers had been that the paper when read had not elicited the desired discussion of the subject introduced; however, it would appear that could not be said of the present paper, as there were already indications of a brisk discussion. He thought that the best thanks of the Institution were due to the author.

One point that occurred to him in the paper was that the author had assumed that the engineer should be expected to present himself at a special examination for each particular appointment. No doubt as a means of admission to the profession examinations are desirable, and for his part he was in favour of making it a necessary qualification for admission to this Institution that candidates should have passed certain stated examinations; but the question was—why should engineering be the only profession in which examinations are considered to be necessary for appointments under public boards? The explanation was to be found in the fact that the profession was wholly unprotected by Statute, and, as a consequence, was swamped by men possessing no recognised qualifications, so much so that the letters "C.E." after a man's name had become a reproach, and signified to many the words "Capital Expender."

In his opinion protection, in the form of licence to practice, would be very beneficial to the engineering profession at large, though, up to the present, the Institution in Westminster had not deemed it necessary to demand legislation in this direction; but he believed that an expression of opinion from the Irish Institution of Civil Engineers would materially assist in bringing about such legislation.

He supposed until this protection was established they would have their examinations. He saw it suggested in the Press recently that examinations should be held for the post of medical officer for a dispensary. Perhaps some one

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will suggest examinations for King's Counsellors. Fortunately the medical and legal professions were protected by Statute, and none but qualified persons were permitted to practice. By law the public were protected from impostors in cases where medical or legal advice was required, and why should it be different in the case of advice on engineering questions, which often entail the safety of life and property?

Mr. James Dillon said a paper of this kind was valuable, but its value would be greater if it were published quickly. He considered that it should be printed and published within about four or six months from the present time.

There was one point with reference to the appointment of County Surveyors that he would like made more clear. He understood from Mr. Cowan's remarks that the qualifying examination took place first and the County Council select him after. He preferred the old way, and hoped the new plan would be abandoned.

Mr. Moore said as he was the first Irishman appointed under the clause specified by the author, he would like to say a few words.

He always had his doubts as to the propriety of these competitive examinations, and whether they got the best men. The country which had gone in very much for competitive examinations was China, and whether the Chinese system had produced the best men was a matter open to question. Of course in the County Surveyors' examinations they insist upon the qualifications. The man specially prepared had a great pull in a competitive examination over the man who had only practical experience.

He thought the old system was much better than the present one. When a vacancy occurs now it was practically known for certain who would be appointed. He considered it was a distinctly retrograde step. The man who qualified best in the examination should be the first man to be appointed,

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and not the man who has the most local influence. A practice had sprung up of appointing men as Assistant Surveyors who were not qualified, with a view to their qualifying afterwards, which was very unfair to the competitors who were qualified.

Mr. Wise said the thanks of the Institution were due to the author for the most useful paper he had presented to them. It would prove very useful to the younger members of the profession.

He was struck very forcibly by the remarks about the expenditure of public money. Engineers who were responsible should be men who had a thorough good training, and who were thoroughly competent to carry out works to a practical and successful issue.

He had seen many cases where men were appointed to carry out works who were totally incapable, simply because they were local so-called engineers.

He believed that as far as the expenditure of public money was concerned, these competitive examinations were absolutely necessary. Of course there are other sides to the question. He thought competitive examinations were of very great importance; at the same time he thought there were some of their younger members who had their heads full of theory, but who had not got enough education in practical engineering.

He thought sooner or later the engineering profession will have to join together and make some move to get some arrangement made whereby every engineer will have to pass through some course of examination before he can put "C.E." after his name.

Mr. Ross said he would like to say a few words from the employers' side. They had heard all about the engineers' side. The engineers say the matter is very important. It was also important for employers; and what employers would

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do was probably more important than what engineers would wish they would do. Looking at it in that light he thought the public generally had an idea that experienced engineers might not come out on top at an examination.

He was inclined to differ from Mr. Cowan in saying that these examinations did not require special training. The public idea was that they did, and he thought the public were right.

There were a great many men who would be qualified for a thousand pound a year post who had forgotten all the formulæ that were necessary to pass these examinations. He thought as a rule engineers in busy practice forgot the mathematical methods of their younger days. Doctors had a better chance, for even when they get to the head of their profession they give hospital lectures every day; but the heads of the engineering profession are not teachers, they very soon forgot the formulæ which you require at your finger ends to pass competitive examinations successfully.

Mr. G. M. Harriss said he hoped the paper would be published. With reference to what the author said about technical education being overdone, he did not agree with that. He considered that technical education in this country had not been touched at all from an engineering point of view. Therefore he would like the author to give them a little more information on the point.

Mr. Cochrane, in reply, said he had to thank the members of the Institution for the very complimentary manner in which they had received his paper, and for the appreciative remarks and criticisms. The conclusions arrived at by him were based on the statistical information he had quoted, which tended to show a scarcity of competitors for professional appointments who possessed the requisite combination of theoretical and practical knowledge.

He referred to Mr. Glover's suggestion, that a possible reason

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for the dearth of candidates might be found in a low rate of pay. No doubt the emoluments are not excessive, but there are many compensating advantages, such as continuous employment and pensions. The rate of pay in the professional posts in the Civil Service compares favourably with that of officers in the Army and Navy. The State is able to obtain its requirements at low rates, including cheap money. While the average run of salaries is not high, special services are, as a rule, recognised, though perhaps not to the same extent as in business concerns or in the employment of corporate bodies, where there is a larger scope for individual enterprise. The large number of applicants, however, willing to accept employment without passing the ordeal of a competitive examination, and apparently otherwise well qualified, tends to show that the lack of candidates is not due to inadequacy of remuneration.

The suggestion for keeping a registry of employment for young engineers would be useful if carried out, though it hardly comes within the province of the Institution. It would serve a most useful purpose, as we frequently hear of engineers asking where they could find a good Assistant, and the question is not always easily answered, notwithstanding the number of young men ready for a situation.

Mr. Dick raised an important question, to which Mr. Cowan, Mr. Price and Mr. Wise also referred—viz., the employment of unqualified men in important local works. This is a matter rather outside the range of the present paper. It is not by any means new, as it has occupied the attention of engineers for the past forty years, and has been found to be beset by some difficulties. An apparent remedy seems to be registration after examination; but this could only be brought about by legislation. The necessity of some protection of this kind, not only for properly qualified engineers, but for the public, is becoming evident, and it is important that the attention of

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the Institution should be kept fixed on these unsatisfactory conditions until a practical remedy is formulated.

The character of the examinations for County Surveyors is sufficiently explained in the paper, wherein the words of the Act, under which it is held, are quoted. The Civil Service Commissioners in their Annual Reports described it as "Open Competition, under 25 & 26 Vict., c. 106." The appointments were invariably offered to the competitors standing highest in the examinations during the whole period from 1869 until the passing of the Local Government (Ireland) Act in 1898. The competitive character of the examination has not been maintained since, as anyone who passes a qualifying examination may be selected by the County Council.

The author expressed his indebtedness to Mr. Cowan for furnishing him with a copy of the examination papers for Assistants to County Surveyors, prepared by him for the Local Government Board. It is remarkable that in these rather elementary subjects the number of marks taken by the candidates should also be low.

There is no doubt the scientific education of the youth of the country has been neglected for some time. The working of the intermediate system of education for the past twenty years has discouraged the study of natural and experimental science. Until about two years ago teachers in the secondary schools complained that under the system then adopted it did not pay to teach science. This has been abundantly proved by the evidence taken before the Commission on Intermediate Education. The work done by the Science and Art Classes, conducted under South Kensington supervision, has not yielded good results in the science branches.

Since the inauguration of the Department of Agriculture and Technical Instruction a new departure has been made, and at the present time there are a greater number of persons under instruction in science and technical education in Ireland

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in proportion to the population than in any other country in Europe. It remains to be seen whether the results will be commensurate with the provision.

The principle of competitive examination had its opponents from its earliest stage, and there seems lately to be a revival of the objection entertained to it as regards professional appointments in the public services. These objections, based as they are on the few comparative failures to obtain suitable men, can hardly be held as discounting the principle of open competition. It rather tends to show the necessity for a modification in the working out of the methods of conducting these examinations. The competitive system is being adopted largely by all public boards. It possesses one great advantage in preventing favouritism in selection, and is gladly welcomed by those on whom the responsibility of selection usually rests. At the present time more than ever, when thoroughness is requisite, and a knowledge of first principles essential, a competitive test of that knowledge before entering the public service seems indispensable.

THE PRESIDENT in conveying the vote of thanks to the author stated it was the feeling of the meeting that the paper should be printed as early as possible and issued to Members in separate form.

At a Meeting of Council held on 18th Nov., 1903, it was resolved to print Mr. Cochrane's paper as a separate volume as recommended by the General Meeting of the Institution.

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EXAMINATIONS, COMPETITIVE AND QUALIFYING.

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APPENDIX A.

APPOINTMENT OF COUNTY SURVEYORS IN IRELAND.

Rules issued by the Local Government Board and Civil Service Commission for Examinations.

A candidate for the position of County Surveyor, if not an existing County Surveyor in Ireland,

(*a.*) must on the last day fixed by the County Council for receiving applications be not less than twenty-six years of age and not more than forty years:

(*b.*) must show that he has been regularly trained as a Civil Engineer and engaged in the practice of his profession in a responsible position in charge of important works for not less than four years; and

(*c.*) must present himself to the Civil Service Commissioners for literary examination under the Scheme set forth in the Schedule annexed.

It will be necessary for all Candidates, if not existing County Surveyors in Ireland, to satisfy the Local Government Board as to age, health, character, and the possession of the necessary practical and professional qualifications, and to satisfy the Civil Service Commissioners as to competency.

Candidates who are existing County Surveyors in Ireland, and have already been certified by the Civil Service Commissioners, will be obliged to satisfy the Commissioners that they have retained their professional knowledge and skill, and the Local Government Board as to age, health, and character.

All Candidates must submit their applications to the County Council within the time fixed by the Council in their advertisement of the vacancy.

A list of applicants will then be forwarded to the Local Government Board, and the Board, after the necessary inquiries have been made, will notify the names to the Civil Service Commissioners.

The result of the examination will be notified by the Board to the County Council, by whom the final selection will be made.

Local Government Board.
Dublin, *August*, 1899.

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EXAMINATIONS FOR COUNTY SURVEYORSHIPS IN IRELAND.

SCHEDULE.

The examination consists of two parts, and will be in the following subjects, viz.:—

Part I.

	Max. No. of marks
Mathematics—including Geometry, Trigonometry, Algebra, Differential and Integral Calculus, and Geometrical Optics	100
Mechanical Philosophy—including Statics and Dynamics, Hydrostatics and Hydraulics, Pneumatics, and Heat regarded as a source of Power	100
Experimental Science—including Inorganic Chemistry, Heat, Electricity, and Magnetism	100
Geology and Mineralogy	40

Part II.

Strength and other properties of Materials, and the Calculation of Stresses and Strains	100
(A.) Railway and Canal Engineering	140
(B.) Marine Engineering—including Harbour, Dock, Sea and Reclamation Works	140
(C.) Hydraulic Engineering—including Water Supply, Sewerage, and Irrigation	140
(D.) County Works—including Architecture, Roads, Drainage, and River Works	140
	1,000

Each of the groups lettered (A.), (B.), (C.), (D.) to include designs, estimates, specifications, and the mechanical contrivances connected with it.

Candidates must pass in one subject in Part I., and must attain such a standard of proficiency in Parts I. and II. combined as shall satisfy the Civil Service Commissioners.

Civil Service Commission.
June, 1899.

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EXAMINATION FOR POSITION OF ASSISTANT TO COUNTY SURVEYOR.

The Local Government Board for Ireland give notice that an Examination of Candidates for qualification as Assistant County Surveyors in Ireland will be held under the direction of the Board at their Offices, Custom House, Dublin, at 10 o'clock, a.m., on Thursday and Friday, the 5th and 6th of February, 1903.

The subjects for examination will embrace those set out in Article 4 of the Board's General Order of the 9th February, 1900, regulating the qualifications for Assistant Surveyors, and a fee of Ten Shillings will be charged to each Candidate to cover the cost of the examination.

Any Candidate who satisfies the Board that he possesses the qualifications prescribed by Article 3 of the Order above mentioned will be eligible for examination on payment of the required fee.

Applications for admission to the examination should be received in this Office before the 2nd February, 1903.

By Order of the Board.

Office of the Local Government Board for Ireland,
Custom House, Dublin,
3rd January, 1903.

APPOINTMENT OF ASSISTANT SURVEYORS FOR COUNTIES IN IRELAND.

COPY OF REGULATIONS (Dated *9th February*, 1900).

1. Every person who is appointed an Assistant Surveyor in any County in Ireland must produce satisfactory evidence to the Local Government Board for Ireland that his health and character are good, and, except in the case of an existing Assistant Surveyor within the meaning of Section 109 (1) of the Local Government (Ireland) Act, 1898, that at the date of the resolution of the County Council appointing him his age was not less than 21 years, or more than 45 years.

2. Every person appointed as aforesaid who

(*a.*) has a diploma or degree in Engineering from a University or College of Science in the United Kingdom, or a

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certificate from Her Majesty's Civil Service Commissioners, that he is qualified to act as a deputy for a County Surveyor; or

(*b.*) is an Associate Member of the Institution of Civil Engineers, London, or an Associate Member of the Institution of Civil Engineers, Ireland, or has a certificate of having passed the Voluntary Examination for Candidates for Surveyorships held by the Incorporated Association of Municipal and County Engineers;

(*c.*) was on the first day of April, 1899, an Assistant Surveyor in a county in Ireland, or if appointed in any such county between the 1st day of April, 1899, and the date of this Order, satisfies the Local Government Board for Ireland that he is fully qualified to discharge the duties of his office,

shall be deemed qualified for the position of Assistant County Surveyor without further examination.

3. Every person appointed as aforesaid who is not qualified under the provisions of the foregoing Article of this Order must produce to the Local Government Board for Ireland satisfactory evidence that he has profited by training in one of the two following ways, that is to say, either

(1.) By service with a County Surveyor, Civil Engineer, or Architect for not less than two years; or

(2.) By attendance at an Engineering School of some University or College of Science in the United Kingdom for not less than one year, and by having been engaged in practical work in connection with Civil Engineering or Building for one year at the least.

4. Every person appointed as aforesaid who is not qualified under the provisions of Article 2 of this Order must, in addition to possessing one of the qualifications specified in Article 3, also pass a qualifying examination to the satisfaction of the Local Government Board for Ireland in the following subjects:—

(1.) English Composition as tested by writing a business letter from rough notes, or a short essay on some subject connected with his profession.

(2.) Arithmetic.

(3.) Mensuration.

(4.) Building construction.

(5.) Construction and maintenance of roads.

(6.) Chain surveying and levelling.

For specimen of Examination Papers, see p. 67.

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APPENDIX B.

Showing Subjects in the Competitive Examinations and the Number of the Professional Staff employed in the principal Departments in Ireland.

PUBLIC WORKS OFFICE (IRELAND).

I. Assistant Engineer. [Fee £6.]

Limited Competition. Limits of Age, 26 and 40.

1. Drawing—
   (*a*) Drawing and Designing of Engineering Works.
   (*b*) Details of Construction (including Theory of Construction in Engineering Works).*
2. Quantities: Taking out quantities from Drawings and measurement of works executed.
3. Estimates and Specifications.
4. Use and Properties of Materials.
5. Surveying and Levelling.

There will be an Oral Examination in subjects 1, 4 and 5.

Candidates must pass to the satisfaction of the Civil Service Commissioners in all the foregoing subjects.

II. Assistant Surveyor of Buildings (2nd Class) in the Architectural Department. [Fee £3.]

Limited Competition. Limits of Age, 24 and 30.

1. English Composition: Writing a business letter from rough notes, or a short essay on some subject connected with the profession.
2. Drawing (simple).
   (*a*) Drawing and Design in Architectural Works.
   (*b*) Details of Construction (including Theory of Construction) in Architectural Works.
3. Quantities: Taking out Quantities from drawings, and Measurement of Works executed.
4. Estimates and Specifications.

†5. Use and Properties of Materials.

†6. Surveying and Levelling,

7. Sanitary Science, as applied to Buildings.

* Engineering Works: Under this head are included Roads, Railways, Canals, Harbours, Docks, Piers and Breakwaters, drainage of marsh lands, and reclamation from the sea.

† In these subjects there will be an oral examination.

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Candidates must pass to the satisfaction of the Civil Service Commissioners in all the foregoing subjects.

NOTE.—The duties of the office necessarily involve the liability to much travelling at all seasons of the year and exposure to all weathers, and therefore no person can be appointed who is not physically robust.

Successful Candidates will be on probation for two years, and no successful Candidate will be confirmed in his appointment unless, during the period of his probation, he satisfies the Commissioners of Public Works in Ireland that he possesses an adequate knowledge of and acquaintance with the Principles of Valuation of Property.

III. DRAUGHTSMAN, ARCHITECTS' BRANCH, AND DRAWING CLERK, LAND LAW BRANCH.

Open Competition. Limits of Age, 18 and 30.

Preliminary Examination. [Fee 10s.]

1. Handwriting.
2. Orthography.
3. Arithmetic (including Vulgar and Decimal Fractions).

Competitive Examination. [Fee 10s.]

1. Geometrical Drawing.
2. Rudimentary Perspective.
3. Elementary Geometry.
4. Construction as regards the several Building Trades.
5. Freehand Drawing (outline).
6. Freehand Drawing (shading and colouring).

Candidates must pass to the satisfaction of the Commissioners in the first five subjects.

LAND IMPROVEMENT INSPECTORS.

Scheme of Examination not yet fixed.

The Professional Staff of the Public Works Office (Ireland) is as follows :—

ENGINEERS' BRANCH.

1 Engineer	£750 to £900
1 Assistant Engineer	400 to 600
Cost of Works Clerk	150 to 200
Office Assistant	300

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SURVEYORS' BRANCH.

3 Principal Surveyors of Buildings	£500 to £650
(1 with an extra £100 per annum for special services.)	
3 Assistants to Principal Surveyors	450 to 500
5 First Class Assistant Surveyors .. .	310 to 450
5 Second Class Assistant Surveyors	200 to 300
(8 Assistant Surveyors have an office allowance of £20 per annum.)	
2 Draughtsmen	70 to 250
Provision for Temporary Draughtsmen ..	575

LAND ACTS LOANS BRANCH.

11 Examiner	£400
2 Inspectors	£300 to 350
1 Inspector	250 to 350
3 Temporary Inspectors	at 250

Future Inspectors will receive £200 per annum, rising to £300.

In addition to the permanent staff above enumerated there are also the following "temporary" posts :—

Fishery Piers' and Harbours' Engineer; Inspector of the Shannon Navigation ; Railway Construction Engineer ; and Superintendents of Works at the Royal Harbours of Kingstown, Howth, Donaghadee, and Ardglass.

There are also about twelve Clerks of Works at salaries of from £3 to £4 per week. Appointments to all "temporary" posts are made by the Board.

LOCAL GOVERNMENT BOARD (IRELAND).

The professional staff consists of one Engineering Inspector (£700 to £900) and two Assistant Inspectors.

These appointments are made by the Board. No scheme of examination has been formulated for the office.

IRISH LAND COMMISSION (including the CONGESTED DISTRICTS BOARD).

SURVEYOR AND DRAUGHTSMAN. [Fee £1.]

Open Competition. Limits of Age, 21 and 28.

1. Handwriting.
2. Orthography.
3. English Composition.

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4. Mathematics, viz. :—Arithmetic; Algebra, up to and including the Binomial Theorem; the theory and use of Logarithms; Euclid, Books I.–IV. and VI.; Plane Trigonometry, up to and including the solution of Triangles; Mensuration.

*5. Land Surveying and Levelling.

Candidates will be required to show what technical education and practical training they have undergone to qualify themselves for a situation of this nature. They must show that they have served for at least two years under a Civil Engineer or Surveyor in good general practice, and that they have been engaged in a responsible position during the greater part of that time in the carrying out of important Surveys.

The staff consists of three Draughtsmen { £160 to £200. £150 to £300.

SUPREME COURT OF JUDICATURE—LOCAL REGISTRATION OF TITLE.

The staff consists of :—

1 Chief Draughtsman	£160 to £200
1 Draughtsman	100 to 175
Do.	100 to 150

DEPARTMENT OF AGRICULTURE, ROYAL COLLEGE OF SCIENCE, DUBLIN.

In the Royal College of Science, now under the Department of Agriculture, there are eight Professors, including a Professor of Descriptive Geometry and Engineering. The salaries are given as from £600 to £700. Two of the Professors receive personal salaries of £750, and one a fixed salary of £600.

GEOLOGICAL SURVEY OF THE UNITED KINGDOM (IRISH BRANCH).

In the Irish branch there is one District Geologist and four Geologists. The staff for the United Kingdom is—

1 Director	£850 to £1,000
2 Assistants to Director	650 to 750
7 District Geologists	500 to 600
31 Geologists	120 to 400

* In this subject there will be an *oral* and *practical* examination.

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GENERAL PRISONS BOARD, IRELAND.

1 Engineering Inspector .. .. .. £400 to £500

GENERAL VALUATION AND BOUNDARY SURVEY OF IRELAND.

Valuer and Surveyor (Second Section).

Subjects of Examination :—

1. Handwriting.
2. Orthography.
3. Arithmetic.
4. English Composition.
5. Land Surveying, including the making and plotting of Surveys; and Land Valuing.
6. *Architectural Surveying and Valuing,† including Draughtsmanship.
7. Practical Farming, including the elements of Geology and Chemistry as applied to Agriculture.

In subjects 5, 6, and 7 there will be an Oral and Practical Examination.

Limits of Age, 22–28.

An official nomination by the Commissioner of Valuation, Ireland, is required for this situation, but the Civil Service Commissioners can give no information as to the means by which nominations may be obtained.

Civil Service Commission,
January, 1902.

The staff of the Valuation and Boundary Survey (Ireland) consists of :—

Commissioner of Valuation	£1,000 to £1,200
Chief Valuer	500 to 600
First Section Valuers and Surveyors ..	315 to 450
Second Section Valuers and Surveyors ..	150 to 300
Temporary Draughtsmen	624
Provision for Staff of Valuers and Surveyors specially employed for Re-Valuation of Belfast, including office rent and clerical assistance	1,500

* This will include questions dealing with measurements of buildings, the general prices of building materials, and the taking out of quantities.
† *i.e.*, Valuing for rating purposes.

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APPENDIX C.

Showing the Subjects of Examination and the Professional Staff employed in the Principal Departments in Great Britain.

ADMIRALTY WORKS DEPARTMENT.

Assistant Civil Engineers (2nd Grade).

I. The limits of age for this situation are 23 and 28. Candidates must be of the prescribed age on the first day of the Examinations.

II. Candidates will be required to show what technical education and practical training they have undergone to qualify themselves for a situation of this nature. They must show to the satisfaction of the Civil Service Commissioners (1) that they have served for at least three years, in a public or private office, under a Civil Engineer or Architect in good general practice, or a Superintending Engineer of one of His Majesty's Dockyards or a Commanding Royal Engineer; or (2) that they have in some other capacity acquired a three years' practical experience on important works; and (3) that they have fully profited by their practical training, and possess the necessary qualifications and experience. Evidence on these points must be sent in at such times and in such manner as the Civil Service Commissioners may appoint. If it prove *primâ facie* satisfactory, the Candidate will be admitted to Examination, subject to such further inquiry as may be necessary.

III. The Examination consists of two parts, and will be in the following subjects, viz. :—

Part 1.	Maximum marks
Mathematics, including Geometry, Trigonometry, and Algebra	200
Mechanical Philosophy, including Statics and Dynamics, Hydrostatics and Hydraulics, Pneumatics, and Heat regarded as a source of Power	200
Experimental Science, including Inorganic Chemistry, Heat, Electricity, and Magnetism ..	200

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PART 2.	Maximum marks	
* Drawing :—(*a*) Drawing and Design of Engineering Works	300	900
(*b*) Details of Construction (including Theory of Construction) in Engineering Works	300	
(*c*) Drawing and Design of Architectural Works	150	
(*d*) Details of Construction (including Theory of Construction) in Architectural Works	150	
Quantities : Squaring dimensions, preparation and examination of builders' accounts, abstracting, getting into bill, and pricing	100	
Estimates and Specifications	100	
* Use and Properties of Materials	200	
* Surveying and Levelling	150	
Sanitary Engineering	200	

No Candidate will be eligible who does not pass in one at least of the heads included in Part 1, and in each of the subjects in Part 2.

MEMORANDUM.

The Civil Service Commissioners are authorised by the Lords Commissioners of the Admiralty to make the following announcements :—

1. Assistant Civil Engineers (2nd Grade) will enter the Admiralty Service on the express understanding that they are liable to serve as required at any of His Majesty's Naval Establishments at home or abroad. No Candidate will be accepted by the Admiralty who fails to satisfy the Medical Director-General of the Navy as to his physical fitness for service abroad.

2. An Assistant Civil Engineer (2nd Grade) on first entry will be on probation for two years. During probation a salary of £180 per annum will be paid, then if the period of probation is satisfactorily passed the salary will be £200 for the third year, and will progress by annual increments of £10 to a maximum of £300.

3. Assistant Civil Engineers (2nd Grade) are eligible for pro-

* There will be an oral examination in subjects marked thus (*). The oral examination in Drawing will be chiefly on the work sent in by the Candidate in the written examination.

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motion without further examination (if selected) through the successive grades of—

Assistant Civil Engineer (1st Grade)—(minimum £300, annual increment, £15, maximum £400)

Civil Engineer—(minimum £400, annual increment £20, maximum £500)

Superintending Civil Engineer—(minimum £600, annual increment £25, maximum £700) :—

to that of Assistant Director of Works—(minimum £850, annual increment £50, maximum £1,000, with an allowance of £200 per annum to the Senior Assistant).

4. Whilst serving in London or at a foreign station salaries (except that of Assistant Director of Works) are further augmented by local allowances to meet increased expense of living, and Unfurnished Official Residences (or allowances in lieu) are granted in the higher ranks both at home and foreign stations.

5. The Engineer Staff of the Admiralty will be interchangeable with the Staff of the Ports, the same prospect of promotion to the higher posts being open to all. It should be clearly understood, however, that promotion will in all cases be governed by merit and not by seniority, and that annual increments of pay are conditional on service being satisfactory.

6. The numbers of the Establishment of each rank are at the present time as follows :—

2 Assistant Directors of Works.
11 Superintending Civil Engineers.
12 Civil Engineers.
22 Assistant Civil Engineers (First Grade).
21 ,, ,, ,, (Second Grade).

12*th November*, 1901.

ASSISTANT SURVEYOR IN THE DEPARTMENT OF THE DIRECTOR OF ENGINEERING AND ARCHITECTURAL WORKS IN THE ADMIRALTY AT THE HEAD OFFICE AND THE OUTPORTS.

Subjects of Examination :—

	Maximum marks
1. Mensuration. Arithmetic, including use of Logarithms. Algebra, including Quadratic Equations ..	200
2. English Composition, writing a business letter from rough notes, making a précis of correspondence on some subject connected with the profession, and writing a short essay (choice of three subjects to be given) on some subject not connected with the profession	300

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	Maximum marks
*3. Taking out Quantities from drawings, abstracting and getting into bill, and measurement of works executed. Reading and interpreting drawings (oral)	300
*4. Estimating and valuing, including analysis of prices	150
*5. Specifications and Contracts—	
(*a.*) For Works.	
(*b.*) For supply of materials, including use and properties of materials	200
*6. Chain Surveying and Levelling	100
Optional :—	
7. The elements of Trigonometry } Only one of these subjects may be taken	100
8. Any one modern language }	
Total	1,250

NOTE.—No Candidate will be eligible who fails to qualify (*i.e.*, to get one-third marks) in any of the subjects numbered 1 to 6. Limits of Age, 21 and 30.

NOTE.—Examinations for the above-mentioned situation do not take place at fixed intervals, but are held only as Candidates are nominated to compete for vacancies. Applications should be addressed to The Director of Works, Admiralty, 21 Northumberland-avenue, London, S.W.

Civil Service Commission,
25*th May*, 1903.

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1. Assistant Surveyors will enter the Admiralty service on the express understanding that they are liable to serve as required at the Head Office or at any of His Majesty's Naval Establishments at home or abroad. No Candidate will be accepted by the Admiralty who fails to satisfy the Medical Director-General of the Navy as to his physical fitness for the service.

2. Assistant Surveyors on first entry will be on probation for two years, and will only be retained in the service if found in all respects satisfactory. They will receive a commencing salary of £150 per annum, rising by £15 a year to £400 per annum, progress beyond £300 per annum being subject to each officer receiving a special certificate of competency from the Director of Works.

* In these subjects there will be an oral examination.

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3. Assistant Surveyors are eligible for promotion without further examination (if selected) through the grade of Surveyor (minimum £400, annual increment £20, maximum £600, progress beyond £500 being subject to each officer receiving a special certificate of competency from the Director of Works) to that of Chief Surveyor (minimum £800, annual increment £40, maximum £1,000).

4. Whilst serving at stations abroad, the salaries of Assistant Surveyors and Surveyors are further augmented by local allowances at rates varying with the locality, to meet increased expense of living, together with free unfurnished official residences or allowances in lieu.

5. It should be clearly understood that promotion will in all cases be governed by merit and not by seniority, and that annual increments of pay are conditional on service being satisfactory.

6. The number of the establishment of each rank is at the present time as follows :—

1 Chief Surveyor.
6 Surveyors.
19 Assistant Surveyors.

AGRICULTURE, BOARD OF (ENGLAND).

Survey Branch.

I. Building Assistant. [Fee £1.]

Open Competition. Limits of Age, 21 and 26.

Subjects of Examination :—

1. English Composition : Writing a business letter from rough notes, or a short essay on some subject connected with the profession.
2. Drawing (simple) :—
   Drawing and Design in Architectural Works.
   Details of Construction (including Theory of Construction) in Architectural Works.
3. Quantities : Taking out Quantities from Drawings, and Measurement of Works executed.
4. Estimates and Specifications.
*5. Use and Properties of Materials.
6. Sanitary Science as applied to Buildings.

No Candidate will be eligible who fails to pass in any of the above-mentioned subjects.

* In this subject there will be an oral examination.

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II. SECOND CLASS DRAUGHTSMAN IN THE SURVEY BRANCH. [Fee 5s.]

Open Competition. Limits of Age, 18 and 25.

Subjects of Examination :—

1. Orthography and Handwriting.
2. Arithmetic (including Vulgar and Decimal Fractions).
3. English Composition.
4. Plan Drawing (including enlarging and reducing plans, and plotting from a simple Field Book), and the elements of Chain Surveying.

*** *All the subjects are obligatory.*

The staff consists of :—

1	Superintending Surveyor	£400 to £500
3	Examiners	200 to 300
1	Building Assistant	100 to 150
4	Draughtsmen	100 to 150
6	Do. (2nd Class)	70 to 95

A retired R. E. officer is at present employed as head of the Survey Branch.

EDUCATION, BOARD OF (WHITEHALL AND SOUTH KENSINGTON).

Geological Survey.

* GEOLOGISTS. [Fee £6]: CURATOR OF THE GEOLOGICAL SURVEY COLLECTION, EDINBURGH.

Usually filled by nomination, subject to a qualifying examination, but sometimes offered for competition. Limits of Age, 20 and 30.

1. English Composition.
2. (*a.*) French (translation from and into); *or*
   (*b.*) German (as in French); *or*
   (*c.*) French and German. [Candidates offering both French and German will only be required to pass in translation *from* these languages.]
3. Physics : the elementary properties of Electricity, Magnetism, Heat, Light, and Sound.
4. Chemistry (Inorganic).
5. Geology.

For staff, *see* page 51.

* University graduates may be admitted to this situation at the discretion of the Civil Service Commissioners without examination under Clause VII. of the Order in Council of 4th June, 1870.

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HOME OFFICE.

(Inspection of Factories and Workshops).

INSPECTORS OF FACTORIES. [Fee £3.]

Nomination or Limited Competition. Limits of Age, 21 and 30.

	Maximum Marks
1. English Composition	200
2. Arithmetic	200
3. Sanitary Science as applied to Factories and Workshops	400
4. Law relating to Factories and Workshops	400
5. Elementary Physics and Mechanics	400
6. History of Industrial and Social Legislation in the United Kingdom	400
7. Chemistry.	400
8. Mechanism	400

The total number of marks obtainable is 2,000.

Candidates must take the first five subjects, and one (but no more) of subjects 6, 7 and 8; and all Candidates must satisfy the Civil Service Commissioners in each of the subjects which they take.

The staff consists of :—

1	Chief Inspector	£1,200
1	Deputy Inspector	800 to £900
6	Superintending Inspectors	550 to 700
1	Electrical Inspector	— 500
17	Inspectors (1st Class)	410 to 500
33	Do. (2nd Class)	300 to 400
34	Do. (Junior Class)	200 to 300
36	Inspectors' Assistants	100 to 150

LOCAL GOVERNMENT BOARD (ENGLAND).

Engineering Department.

The staff consists of the following—

1	Chief Inspector	£1,100 to £1,200
1	Deputy Inspector	900 to 1,000
17	Inspectors	600 to 800

No scheme of examination has been formulated for this office. The Deputy Chief Inspector and five Inspectors receive pensions from the Army Vote. The appointments are made by the Board.

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MINT.

I. Assistant Assayer. [Fee £6.]

Limited Competition. Limits of Age. 18 and 30.

	Marks
1. Practical Assaying of Gold and Silver Bullion ..	500
2. Analytical Chemistry (Metals and Alloys)	100
3. Metallurgy of Gold and Silver	100
4. Theoretical Chemistry (Inorganic)	100
5. Practical Physics	100
[Fundamental Physical Measurements and either of the following :— *a.* Heat (Practical). *b.* Electricity (Practical).]	
6. Mathematics (Algebra up to and including the Binomial Theorem, Logarithms, Mensuration and Trigonometry to solution of Triangles)	100

Candidates will be required to pass in Practical Assaying and two other subjects.

II. Clerk in the Operative Department of the Royal Mint. [Fee £1.]

Open Competition. Limits of Age, 20 and 25.

1. Handwriting and Orthography.
2. Arithmetic.
3. Machine Drawing and Construction.
4. Applied Mechanics and Mechanism (including a practical knowledge of engineering work).
5. Applied Electricity.

All Candidates must qualify in subjects numbered 1 *and* 2, *and in two of the remaining subjects. No Candidate may take up more than two of the subjects numbered* 3, 4, *and* 5.

Candidates will be required to show what technical education and practical training they have undergone to qualify them for the duty of taking charge of machinery in an engineering establishment and superintending workmen.

The staff consists of :—

1 Chemist and Assayer of Mint	£700 to £900
3 Assistant Assayers	350 to 550
1 Superintendent of Operative Department	700 to 900
2 Assistant Superintendents of Operative Department	310 to 400
10 Clerks in Operative Department	135 to 300

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WORKS, OFFICE OF (ENGLAND.)

I. Assistant Examiner. [Fee £3.]

Open Competition. Limits of Age, 23 and 30.

1. English Composition: Writing a business letter from rough notes, or a short essay on some subject connected with the profession.
2. Drawing:—Details of Construction (including Theory of Construction) in Architectural Works.
*3. Quantities:—(*a*) Squaring dimensions, preparation and examination of builders' accounts, abstracting, getting into bill and pricing.
   (*b*) Taking out quantities from drawings and measurement of works executed.
4. Use and properties of Materials.

No Candidate will be eligible who fails to pass in any of the above-mentioned subjects.

Candidates will be required to show what technical education and practical training they have undergone to qualify themselves for a situation of this nature. They must show (1) that they have served for at least five years in a public or private office under an Architect, Builder, or Surveyor; (2) that the works on which they have been engaged during those years were such as to afford them the opportunity of gaining a satisfactory knowledge of their profession; and (3) that they have fully profited by their practical training, and possess the necessary qualifications and experience.

II. Assistant Architect and Surveyor. [Fee £3.]

Limited Competition. Limits of Age, 23 and 35.

1. Drawing:—Drawing and Design of Architectural Works; details of Construction (including Theory of Construction) in Architectural Works.
2. Specifications.
3. Quantities and Estimates.
4. Use and properties of Materials.
5. Surveying and Levelling.
6. Sanitary Engineering.
7. Principles and Practice of Valuation, Easements, &c.

No Candidate will be eligible who fails to pass in any of the

* In this subject there will be an oral examination.

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above-mentioned subjects. The Examination will be partly written and partly oral.

Assistant Architects and Surveyors are liable to be called upon to serve in China, Japan, or other stations in the East.

Assistant Surveyor (2nd Class).

Subjects of Examination :—

1. Drawing :—Drawing and Design of Architectural Works. Details of Construction (including Theory of Construction) in Architectural Works.
2. Specifications.
3. Quantities and Estimates.
4. Use and properties of Materials.
5. Surveying and Levelling.
6. Sanitary Engineering.
7. Principles and Practice of Valuation, Easements, &c.

The Examination may be partly written and partly oral, as may be deemed desirable on each occasion.

Limits of Age, 23–35.

An official nomination is required for this situation, but the Commissioners can give no information as to the persons from whom or the means by which such nominations may be obtained.

III. Clerk of Works.* [Fee £2.]

Limited Competition. Limits of Age, 25 and 40.

1. English Composition : Writing a business letter from rough notes, or a short essay on some subject connected with the profession.
2. Drawing, simple : Details of Construction (including Theory of Construction) in Architectural Works.
3. Quantities : Taking out quantities from drawings and measurement of works executed.
4. Estimates and Specifications.

†5. Use and properties of Materials.
†6. Sanitary Science as applied to Buildings.

No Candidate will be eligible who fails to pass in any of the above subjects.

* Examinations for Scottish posts will be held in Edinburgh, and will proceed upon Scottish methods of construction and materials, and on the Edinburgh mode of measurements.

† In these subjects there will be an oral examination.

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Office of Works and Public Buildings (*London*).—The professional staff of this office consists of the following :—

2	Principal Architects and Surveyors ..	£800 to £1,000
5	Architects and Surveyors	500 to 750
11	Assistant Architects and Surveyors (1st Class)	310 to 400
19	Assistant Architects and Surveyors (2nd Class)	150 to 300
2	Draughtsmen	210 to 250
6	Clerks of Works	250 to 300
1	Chief Engineer	500 to 750
1	Deputy Engineer	150 to 300

PATENT OFFICE.

(Including REGISTRY OF DESIGNS AND REGISTRY OF TRADE MARKS.)

I. ASSISTANT EXAMINER. [Fee £5.]

Open Competition. Limits of Age, 20 and 25.

1. English Composition (including Spelling and Handwriting).
2. Geometry (plane and solid).
3. Mechanics and Mechanism.
4. Chemistry.
5. Electricity and Magnetism.
6. General Physics, Hydrostatics, Heat, Light and Sound.
7. French or German (translation from the language into English).

No subjects are obligatory, but Candidates must obtain such an aggregate number of marks in the Examination as a whole as may indicate, in the judgment of the Civil Service Commissioners, a competent amount of general proficiency.

II. DRAUGHTSMAN. [Fee 10s.]

Open Competition. Limits of Age, 22 and 30,

1. Handwriting.
2. Orthography.
3. Arithmetic (including Vulgar and Decimal Fractions).
4. Machine Construction and Drawing.

Candidates will be required to show what preliminary training or technical education they have undergone to qualify themselves for a situation of this nature. They must have been engaged for at least three years during the last five years in a Drawing office, and must show that they have profited by that training.

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The staff at the Patent Office consists of :—

Comptroller-General	£1,200 to	£1,500
Registrar of Designs		1,000
1 Chief Examiner	800 to	1,000
4 Principal Examiners	600 to	700
3 Examiners	600 to	700
8 Deputy do.	500 to	580
13 Assistant Examiners	250 to	500
47 do.	150 to	450

PRISONS DEPARTMENT (ENGLAND).

* CLERK AND DRAUGHTSMAN IN THE OFFICE OF THE SURVEYOR TO THE COMMISSIONERS OF PRISONS. [Fee 12s. 6d.]

Open Competition. Limits of Age, 21 and 35.

The Examination will be in the following subjects, viz. :—

1. English Composition : Writing a business letter from rough notes, or a short essay on a subject connected with the profession.
2. Drawing : Drawing and Design of Engineering Works.
   Details of Construction (including Theory of Construction) in Engineering Works.
   Drawing and Design of Architectural Works.
   Details of Construction (including Theory of Construction) in Architectural Works.
3. Quantities :—(*a*) Squaring dimensions, preparation and examination of builders' accounts, abstracting, getting into bill and pricing.
   (*b*) Taking out quantities from drawings and measurement of works executed.
4. Estimates and Specifications.

†5. Use and properties of Materials.

6. Sanitary Science as applied to Buildings

No Candidate will be eligible who fails to pass in any of the above-mentioned subjects.

The staff consists of :—

1 Surveyor	£700 to	£900
1 Assistant Surveyor	300 to	400
1 Clerk and Draughtsman	150 to	200
1 Clerk of Works	225 to	275

* Candidates will be required to show what technical education and practical training they have undergone to qualify themselves for a situation of this nature.

† In this subject there will be an oral examination.

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WAR OFFICE.

Civil Staff of the Military Works Department.

I. The limits of age for this situation are 21 and 30, and Candidates must be of the prescribed age on the first day of the competitive examination.

II. Candidates will be required to show what technical education and practical training they have undergone to qualify themselves for a situation of this nature. They must show (1) that they have served, for at least three years, in a public or private office, under an Architect, Builder, Civil Engineer, or Surveyor; (2) that the works on which they have been engaged during those years were such as to afford them the opportunity of gaining a satisfactory knowledge of their profession; and (3) that they have fully profited by their practical training, and possess the necessary qualifications and experience. Evidence on these points must be sent in at such times and in such manner as the Civil Service Commissioners may appoint.

Assistant Surveyor.

III. The examination will be in the following subjects, viz. :—

Obligatory.

1. English Composition: Writing a business letter from rough notes, or a short essay on some subject connected with the profession.

*2. Drawing: (*a.*) Details of Construction (including Theory of Construction) in Engineering Works.
(*b.*) Details of Construction (including Theory of Construction) in Architectural Works.

3. Quantities (*a.*) Squaring dimensions, preparation of builders' accounts, abstracting, getting into bill and pricing.
(*b*) Taking out quantities from drawings and measurement of works executed.

4. Estimates.

*5. Use and properties of Materials.

*6. Surveying and Levelling.

*7. Sanitary Engineering.

No Candidate will be eligible who fails to pass in any of the above-mentioned subjects.

Optional.

8. Euclid (the first three Books).
9. Algebra, including quadratic equations.
10. Plane Trigonometry.

*In these subjects there will be an oral examination. The oral examination in Drawing will be chiefly on the work sent in by the Candidate in the written examination.

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IV. A fee of £5 will be required from every Candidate attending the Examination.

V. Application for permission to attend an examination must be made at such times and in such manner as the Commissioners may appoint.

Candidates must be ready to serve at any Station at home or abroad.

NOTE.—The salary of an Assistant Surveyor, Royal Engineer Civil Staff, commences at £180 per annum, and rises by annual increments of £10 to £280, with an ultimate prospect of reaching £500 a year.

For staff employed in the Civil Branch of the Royal Engineer Department, *see* page 25, *ante*.

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APPENDIX D.

SPECIMENS OF EXAMINATION PAPERS.

ADMIRALTY—ASSISTANT CIVIL ENGINEER.

DRAWING. (A.)

(Drawing and Design of Engineering Works.)

[*The Candidate is to attempt only* ONE *of the following questions. The drawing is to be inked in and fully written up; sections to be tinted.*]

1. Draw to a scale of 2 ft. to 1 inch the midship section of a ship caisson for a dock entrance 80 ft. wide and with a head of water of 30 ft. at low water. Show all the internal fittings, and describe the operation of removing the caisson either in or out of position.
2. Draw to a scale of 10 ft. to 1 inch the cross-section of a railway station 200 ft. wide; the roof to be carried on two side walls and centre columns—the height from the platform level to the springing of the roof to be 25 ft.; to have one central platform 30 ft. wide and two side platforms 20 ft. wide each; rail level 3 ft. below platform, the rails need not be shown. Draw to an enlarged scale the elevation of one half of one of the principals, giving approximate dimensions.
3. Draw to a scale of 8 ft. to 1 inch the cross-section of a warehouse 60 ft. wide inside, on a dock side, suitable for heavy mixed merchandise; to have a basement 15 ft. below quay level; the first floor to be 20 ft. above quay level, and the next two floors 15 ft. from floor to floor. Draw to an enlarged scale the details of the floors and the roof.

DRAWING. (B.)

(Details of Construction—including Theory of Construction—in Engineering Works.)

[*Six questions only are to be answered, three from Section I. and three from Section II. When drawings are necessary for illustration, they are to be sketches only, in either ink or pencil, and not finished drawings.*]

SECTION I.

1. What is the moment of inertia about its minor axis of a rectangular section 6 inches by 4 inches, and what is its radius of gyration?

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2. Draw the stress diagram for the frame shown in Fig. 1, assuming the joints to be loaded with equal weights in the direction of the arrows. Mark the ascertained stresses on the diagram, and state whether the members are in tension or compression.

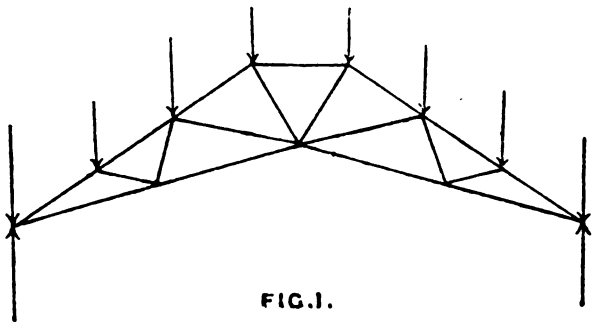

FIG. 1.

3. What load will a cast-iron column bear with a factor of safety of 5 of the following dimensions :—Length 20 ft. fixed at each end, external diameter 9 inches, thickness of metal $\frac{5}{8}$ inch ?
4. What pressure will a cylindrical boiler carry with a factor of safety of 6, the diameter of the boiler being 6 ft. and the thickness of plates $\frac{1}{2}$ inch ? Assume the tensile strength of the plates to be 32 tons per sq. inch, and the efficiency of the joints 90 per cent.
5. A sluice door 2 ft. square is placed in a dock gate 25 ft. below the surface of the water ; what is the pressure on the door
6. The cable of a suspension bridge 500 ft. span has a dip of 50 ft. and carries a uniformly distributed load of 500 tons what is the stress in the cable at the towers and at the centre of the span ?

SECTION II.

7. Sketch or describe two different types of hydraulic passenger lifts.
8. Sketch a collecting tank for collecting the water of a spring, showing the pipe conveying the water to the reservoir.
9. Sketch the cross-section of a 60 ft. road for a town with heavy wheel traffic and two 10 ft. side walks.
10. Sketch a manhole for an oval sewer 4 ft. × 3 ft. at a depth of 10 ft. below the ground.

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11. Sketch two views of a 90 lb. rail and chair complete; plan and side elevation showing section of rail.
12. Sketch a cast-iron bollard for a dock quay, showing the method of securing it.

SANITARY ENGINEERING.

[*Not more than* EIGHT *of the following questions to be answered.*]

1. In what particulars does a bacteria-bed differ from an ordinary sewage filter?
2. Describe a slop water-closet and name its merits and demerits.
3. Explain the expressions "separate system" and "combined system" of sewerage.
4. What fittings and appliances are necessary for the supply of hot and cold water to a slipper bath?
5. What is considered the best aspect for a dwelling-house? State the reasons.
6. A properly ventilated fever ward containing four beds has to be efficiently heated by means of steam radiators, how would you determine their size, number and position?
7. An area of 100 acres of a manufacturing town is to be laid out with streets, and cottages erected thereon. The town water supply for all purposes averages 30 gallons per head of the population, the drainage is to be on the separate system; how many gallons per 24 hours would be added to the town sewage from this area?
8. Show by a sketch, not to scale, how a sink in an infectious diseases hospital should be connected with the drain.
9. What is the hydraulic mean depth of a 36-inch diameter sewer when running two-thirds full?
10. How are stoneware drains laid and jointed? Describe the methods of jointing in general use, and explain the difference between drains laid on the Lynde deflection principle and those laid in the ordinary way.
11. Which of the sanitary fittings of a dwelling are most liable to be affected by frost? What means should be taken to protect them?
12. What are the essentials of a good water-closet apparatus?

DRAWING. (C.)

(Drawing and Design of Architectural Works.)

1. Make design for an ornamental gateway entrance to a public park, with central archway for two carriages to pass through together and two side arches over footways.

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Draw elevation and section to scale of 8 feet to an inch.

Or, as an alternative,

Design for a front elevation a four storey city building having a frontage of 20 feet, consisting of shop front and doorway on ground floor, bay-window over same on 1st and 2nd floors, and gabled storey in roof.

Draw to scale of 8 feet to an inch the front elevation and section.

2. Make sketches of any three of the following :—
   Modillion, belonging to a Corinthian cornice.
   Stone balcony upon two trusses, with balustrade over.
   Window in a stone rusticated basement.
   Moulded stone string-course, enriched with egg-and-dart and Grecian fret.
   Ornamental stone Gothic cross on a gable.
   Oak bench-end, with Gothic tracery in panel.
3. Design a boat-house to be erected on the sea-shore for a life boat and its appliances. Draw plan, front elevation, and part of side elevation to scale of 8 feet to one inch.

Or, as an alternative,

Design a swimming bath for a school of fifty boys.

Draw plan, front elevation, and part of side elevation to scale of 8 feet to an inch.

Drawing. (D.)

(Details of Construction, including Theory of Construction, in Architectural Works.)

[*Rough pencil sketches only, and not finished drawings, are required—scales optional.*]

1. Draw plan and section of roof trusses and purlins required at the crossing of two open timbered roofs, each 30 ft. span, over a large room; with collar-beams 5 feet above the springing of roof, and no tie beams. Indicate the strains of the principal timbers.
2. Give section and elevation of the foundations, and part of lower storey, of a two and a half brick wall of a warehouse on clay soil, with piers 21″ × 14″ in same (12 ft. apart) supporting the floor girders. Show inverted arches, and damp-course.
3. Draw plan and section of a geometric staircase of wood, 4 feet wide, in two flights side by side, one of them against a wall, with well-hole 12″ wide and winders. Height of storey, 12 feet. Show the supports, and sketch detail of two steps.

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4. Draw plan and section of a stone portico with detached columns, two stone steps, landing and doorway, at the front entrance of a town house. Show the jointing.
5. Make plan and section of a lead flat roof, surrounded by three brick parapets and a wall, over a room 25 ft. square. Outlets for rain water to be arranged at one end and at one side of the roof. Give sketch details of rolls, drips and flashings.

Use and Properties of Materials.

[*Not more than* EIGHT *of the following questions to be answered.*]

1. What are the component parts of good building mortar?
2. Describe the appearance of dry rot and of wet rot in timber, the conditions under which each occurs, and the measures which should be taken to prevent them arising.
3. What are the constituents of good brick earth? Describe the external and internal appearance of a Staffordshire blue brick.
4. What materials are used in covering roofs? Describe each kind of material and the points to be observed in selecting it.
5. What kinds of wood block flooring are in general use? What woods are most suitable for this purpose? How are the blocks laid and treated?
6. Describe the materials used and the special construction adopted to render the floors of buildings fire-resisting.
7. What materials are used for deadening sound in buildings? Which do you consider the most suitable for the purpose, having in view their sanitary and fire-resisting properties?
8. What is terra cotta? How is it made? What are its uses and its advantages and disadvantages as a building material?
9. Name six different kinds of building stone, and state the character and properties of each.
10. How would you judge of the quality of timber? Name some of the woods used in building, and state their chief characteristics and uses.
11. Describe in trade terms the different operations necessary and the materials used in interior plaster, in order to secure first-class work.
12. Describe the appearance of Portland cement and the tests which should be applied to it.

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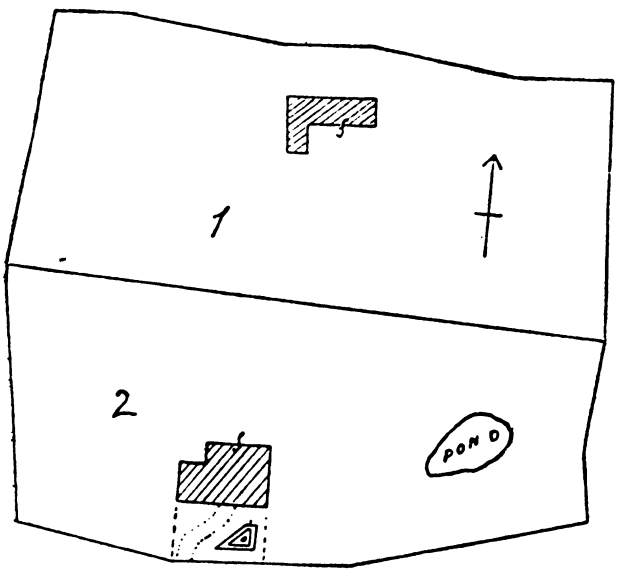
Surveying and Levelling.

1. The accompanying sketch is supposed to represent an actual piece of land, which has to be surveyed with a chain and tape as measuring instruments. Select the stations required for the survey, sketch the positions of base lines, and write down the entries of any one of the base lines in the supposed survey of the enclosures, in the usual form



of field-book, with the use of a scale of 3 chains to 1 inch applied to the sketch plan, so that a plan of the property could be plotted to any desired scale from those fieldbook entries.

Why is it not necessary to measure a base line in the triangulation of a survey a second time in order to prove its accuracy?

2. Compute the area of *one* of the two enclosures marked 1 and 2 upon the plan in Question 1, including the space occupied by any house, pond or shed in the enclosure, and express the result in acres, roods and poles.

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3. Rising ground of a moderate slope intervenes between the ends of a base line, so that the station at one end cannot be observed from the level of the station at the other end. Show how the line may be accurately set out with the use of a few ranging rods, so as subsequently to chain its total length.
4. In what manner would you record measurements from a base line to some well-defined point in a survey, such as the corner of a building, which it was essential to fix in position accurately?
5. State what form of level book you prefer. Sketch a page giving the headings and their use, adding the reasons why you prefer this method to other systems with which you may be familiar. What kind of notes would you enter in the field upon the page reserved for remarks?
6. If you were levelling in the direction of a bright sunset, what precautions would you take as regards the relative positions of your instrument and the level staff? State the instructions you would give the staffholder in order to ensure accurate records when at work over undulatory ground.
7. Describe the difference to be observed in levelling the parallel plates of a dumpy level or of a theodolite (1) when working with an instrument to be adjusted by four plate screws, and (2) when working with an instrument to be adjusted by three plate screws.
8. Explain, with the aid of a sketch, the usual adjustments to test the accurate traverse of both the horizontal and the vertical circles in a transit theodolite. Also describe the process of taking and booking an angle with the use of a theodolite set up over the intersection of two base lines.
9. Describe, by the aid of a sketch, the usual mode of continuing the ranging of a base line over a hill with the use of a theodolite and ranging rods.

QUANTITIES.

(Squaring Dimensions, Preparation and Examination of Builders' Accounts, Abstracting, Getting into Bill, and Pricing.)

1. Square the dimensions and abstract and bill the items on the accompanying sheet (marked Question 1).
2. Price the accompanying Bill of Measured Works (marked Question 2) at London prices. (If you are not familiar with London prices you may use others, stating the district in which they are current.) The prices are not to be extended.

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QUANTITIES.—*For Question* 1.

64 6 26 3	Take off top soil not exceeding 1′ 0″ deep, and cart away.	
110 4 3 4 1 9	Excavate surface trenches ; and Return, fill and ram.	
110 4 3 4 1 6	Cement concrete as described ; and Deduct return, fill and ram ; and Add cart away.	
	2/·4½ 110 4 9 111 1	
111 1 9	2½ B.	*Foots.*
111 1 14 6	1½ B.	*up to eaves.*
110 4	Extra labour to beam filling on 1½ B.	
111 1 1 2	Damp proof course of two courses of slates, breaking joint and well bedded in cement, neatly pointed in cement where visible.	
112 8 13 9	Extra on ordinary brickwork for best Fareham red facings, and finished with a neatly struck weathered joint.	
108 0 14 3	Add.	*Inside.*

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QUANTITIES.—*For Question* 1.

4/	7 0	
4/	7 0 3	½ B. Deduct. *Windows.*
4/	7 5	
4/	7 5 3	1 B. Deduct.
4/	11 6	Centering 5″ semi-circular soffit.
4/	12 2 9	Centering semi-circular arch.
4/	11 6 5	Extra on ordinary brickwork for rubbed and gauged arch in red Farehams, neatly pointed to match facings.
4/	12 2 5	
4/	12 8 9	Do., and Ddt. red facings.
4/	13 4 9	
4/	13 4	Circular cutting on facings.
4/	14 0	
4/	No. 1	Bed and point window frame both sides, the sill bedded in white lead.

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QUANTITIES.—*For Question* 1.

4/ 6/	·9		$4\frac{1}{2}'' \times \frac{3}{8}''$ fillets as fixing pieces and bldg. in without mortar.
4/	No. 1		Semi-circ. arch, 13′ 4″ × ½ brick soffit by 1 brick high.
4/	7 5		9″ × 4½″ York stone cill, rubbed, sunk, weathered, and throated.
4/	No. 2		Quoined ends; and Ends cut and pinned to facings.
4/	No. 1		Sill bedded hollow, and made up and pointed at completion.
4/	7 0		Ddt. red facings.
4/	7 0 1 0		
4/	7 5		
4/	7 5 3		
4/	7 5		$1\frac{1}{2}'' \times \frac{1}{8}''$ galvanised wrot iron tongue and bedding in white lead; and Groove in oak; and Groove in York.
4/	No. 1		Semi-headed 3-light window 7′ 5″ wide, 4′ 0″ high with solid frame of 4½″ × 4″ *oak* framed cill, double sunk, weathered, check throated, moulded and rounded 4½″ × 4″ (finished), fir

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QUANTITIES.—*For Question* 1.

		framed head circular to arch, rebated, double moulded, and with keyed heading joints and two 4½″ × 3½″ fir framed mullions double rebated, 4 times moulded and hollow grooved for water check, and 1¾″ deal moulded casements with stout bars in small squares, the side ones fixed, the centre do., hung folding and hollow grooved for water check, and the bottom rail splay rebated.
4/	No. 2	Pairs 3″ wrot iron butts.
4/	No. 2	Wrot iron casement, stay-bar fastenings, p.c. 5*s.* each.
4/ 8/	10 1 0	21 oz. sheet glass *in one square.*
4/ 2/	10 1 0	Do. to shapes, do.
4/ 2/	10 1 2	Do. do., do.
4/ 2/	1 3 1 1	Do. do., do.
4/ 2/	1 0 1 4	Do. do., do.
	89 6 13 3	Plain Broseley tiling with nibs laid to a 4″ gauge, and nailed with one composition nail to each tile ; and 2″ × 1″ deal battens well nailed to boarding ; and 1″ rough close jointed boarding for tiles.
	178 0	Extra labour and materials to double course of tiles at eaves.

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QUANTITIES.—*For Question* 1.

	178 0	3″ × 1½″ splayed tilting fillet.
2/	19 0	Plain ridge tiles set and pointed and jointed in cement.
	No. 2	Fair ends with neat cement finishing
2/ 2/	5 0	Tile and cement verge ; and
2/	3 3	Tilter as before.
	3 0 8	1¼″ deal gutter boards and framed bearers in narrow widths behind chimney stack ; and Inodorous roofing felt.
	No. 1	Short length 2″ deal rounded roll.
	5 3 2 4	5 lbs. lead gutter.
1/·2	2. No. 2	Ends roll bossed.
	No. 2	Small deal gussets at ends of gutter.
	3 3 7	5 lbs. lead flashing.
2/	3 3	Wedging flashings with cast lead wedges ; and Rake out joints of brickwork for and point flashings in cement.
	66 0	5″ cast-iron half-round eaves gutter with socketed joints put together with red lead and bolted and fixing, including wrot iron brackets and zinc clips ; and (1) and (3) in and out.

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QUANTITIES.—*For Question* 1.

	No. 2	Angles.
	No. 2	Stopped ends.
	No. 4	Outlets with short sockets cast on ; and Strong galvanised iron wire domical covers with legs.
2/	No. 4	Large 3-light frames, knot, prime, stop and paint four additional coats ; and Once varnish.
2/	No. 64	Squares do.

QUANTITIES.—*For Question* 2.

Yards	Feet					£	*s.*	*d.*
100	—	—	Cube	Excavate surface trenches not exceeding 6′ 0″ deep, and throw out - - - -				
30	—	—	,,	Temporarily deposit earth and return, fill in and ram around foundations - - -				
70	—	—	,,	Fill earth into carts and cart away two miles - -				
40	—	—	,,	Concrete composed of six measures clean stone ballast and one of Portland cement properly mixed, lowered into trenches and well punned and levelled to receive the footings -				
Rods								
5	—	—	Super	Reduced stock brickwork in mortar - - -				
2	—	—	,,	*Extra only* for brickwork being built in cement - -				

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QUANTITIES.—*For Question* 2.

	Feet					£	s.	d.
	20	--	Run	Cutting and bonding 1½ brick wall to old - -				
	20	—	,,	Rake out for and point in cement to lead flashings -				
	10	—	,,	Do. stepped - - -				
		No.	20	Ends timbers cut and pinned or built in - - -				
		,,	30	Heels of roof trusses do.				
		,,	10	Extra labour and waste and cement to semi-circular arches in cement average 13′ 5″ girth ½ brick soffit by 1 brick high -				
		,,	1	Flue parged with cow dung and hair and cored out at completion - - - -				
		,,	1	Setting only stove in 3′ 0″ opening, the back lined with fire bricks, and including the requisite fire bricks, fire lumps and clay - - -				
	12	—	Super	2½″ hard York stone rubbed hearth, including jointed edges and bedding in mortar - -				
		No.	6	3″ do. tooled templates 14″ × 18″ rounded on edge and setting in cement - - - -				
	60	—	Super	Centering to semi-circular soffit				
	100	—	Cube	Fir framed in roofs - -				
Squares 20	—	—	Super	1″ rough close jointed deal boarding to roofs in batten widths, and nailing - - -				
	20	—	,,	1¼″ deal gutter boards and framed bearers - -				
	100	—	Run	3″ × 1½″ deal splayed titling fillet				
	20	—	,,	5″ × 1½″ do. wrot and double chamfered and framed ridge -				
		No.	10	Heads of bolts let in and pelleted				

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QUANTITIES.—*For Question* 2.

				Wrot Deal.		£	s.	d.
Squares	Feet							
10	—	—	Super	1¼″ tongued batten flooring laid straight joint with splayed headings, the boards compressed into their places with patent levers, and punched and cleaned off at completion -				
	30	—	Run	7″ × 1″ moulded and skirtings and backings - - -				
	50	—	Super	1¾″ four panel moulded and square door - - -				
	20	—	,,	1½″ double rebated jamb linings and tongued angles and backings - - - -				
	15	—	Run	4½″ × 3″ wrot all round and framed rebated and double beaded door frame -				
	20	—	,,	Labour scribing 1¼″ - -				
	20	—	,,	Small bed moulding and housing to underside of window board -				
				No. 4 returned and mitred ends -				
	120	—	,,	5″ cast-iron half-round eaves gutter with socketed joints put together with red lead and bolts and fixing, including wrot iron brackets and stout screws				
				No. 4 stopped ends - -				
				No. 2 outlets and short sockets cast on - - - -				
Cwts.	qrs.	lbs.						
2	1	14	—	Wrot iron in forged straps including perforations and fixing by Carpenter - - -				
30	—	—	—	Milled lead and labour in gutters, flats, flashings, &c. - -				
	Feet	ins.						
	40	—	Run	Labour welted edge - -				
	40	—	,,	Close copper mailing - -				
		No.	6	Ends of roll bossed - -				

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QUANTITIES.—*For Question* 2.

	Feet					£	s.	d.
	100	—	Super	21 oz. best quality sheet glass and glazing in squares not exceeding 3″ 0″ super - - -				
	10	—	,,	21 oz. do. do. and bedded in washleather - - -				
Yards 20	—	—	,,	Paint two coats read lead and oil on iron before, and two after, fixing - - - -				
40	—	—	,,	Knot, prime, stop and paint four additional coats on wood work, finished plain tints to choice				

ESTIMATES AND SPECIFICATIONS.

1. It is proposed to form a basement in a London building adjoining a house without a basement. Write a specification of the work required in under-pinning the side wall of the latter.
2. Specify any eight of the following :—
   Portland cement; lime for concrete; Portland stone for dressings; Bath stone for dressings; York stone for steps; deal for joinery; wainscot; the best mahogany; plasterers' setting stuff; cast iron; wrot iron; steel.
3. (*a.*) Write a full specification in all trades for forming a new window 4′ 0″ × 8′ 6″ (sight measurement) in a blank wall, two bricks thick, at the side of a public building. Wainscot sashes and frames, inside finishings wainscot, red facings outside.
   (*b.*) Make an estimate of the cost of the foregoing.

Or,

4. (*a.*) Specify a steel riveted girder to carry a 1½ brick in cement wall 15′ 0″ long, 12′ 0″ high.
   (*b.*) Make an estimate of the cost of the foregoing.

MATHEMATICS.

(Geometry, Algebra and Trigonometry.)

(*In Geometry the demonstrations need not be those of Euclid. The circumference of a circle is* 3·14 *times its diameter.*)

1. If two triangles are equiangular, prove that their sides are proportionals.
   Hence show that if two parallel straight lines are cut by lines

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radiating from a point, the segments of one are proportional to the segments of the other.

2. Prove that the three angles of a triangle are together equal to two right angles, and establish a formula for calculating the sum of the angles of a polygon of n sides.

ABCDEF is an equilateral hexagon, and each of the angles A, C, E is double of each of the angles B, D, F; find the number of degrees in each angle.

3. Draw a triangle with vertical angle 90° and sides containing it 1″ and 2″·4. Describe a circle to touch the base and the two sides produced.

Show, by measurement from your figure, that the distance from the vertex to the point of contact of either of the sides is half the perimeter of the triangle.

4. Prove that the angles formed by a chord of a circle and the tangent at its extremity are equal to the angles in the segments into which the circle is divided by the chord.

5. Simplify

$$\frac{\left(\frac{a}{b}-\frac{b}{a}\right)^3+3\left(\frac{a}{b}-\frac{b}{a}\right)}{\left(\frac{a}{b}+\frac{b}{a}+1\right)\left(\frac{a}{b}+\frac{b}{a}-1\right)}$$

and find (to three decimal places) the value of

$$\frac{4^{-\frac{3}{2}}-9^{-\frac{3}{2}}}{4^{-\frac{1}{2}}+9^{-\frac{1}{2}}}.$$

6. Calculate, as accurately as the tables permit,

(i.) $848{\cdot}2 \times 0{\cdot}00456$.

(ii.) $59 \times (1{\cdot}002)^{1{\cdot}03} \times (1{\cdot}02)^{{\cdot}31} \times \tan 75° \, 23.'$

7. The square of x varies as $t + a$ and a is constant: also $x = 4$ when $t = 3\frac{3}{5}$ and $x = 5$ when $t = 9$; find the value of x when $t = 54$.

8. Expand $(1 - x)^{-\frac{3}{2}}$ to five terms by the Binomial Theorem.

If a and b are so small that their squares may be neglected, find the value of

$$\frac{1}{(1-ax)^2\,(1-bx)^3}$$

in a form free from fractions.

9. With your protractor draw an angle of 37°. Make a suitable construction and read off from your figure the value of sin 37° and tan 37°.

Write down also the values of tan 127° and sin 143°.

10. Prove that in a triangle (A being an acute angle)

$$\cos A = \frac{b^2+c^2-a^2}{2bc}.$$

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11. In the triangle ABC

$$AB = 422{\cdot}4 \text{ yards};$$
$$BC = 250 \text{ yards};$$
$$\text{angle } ACB = 59^\circ\ 23'.$$

Find the area of the triangle.

12. Trace the graph of sin X (the graph is a curve showing how the value of sin X changes as X changes from 0° to 360°). What are the greatest and least values of sin X, and the corresponding values of X?

Mechanical Philosophy. (1.)

1. Show that if a single twisting moment T is applied to a shaft of radius r, the maximum stress produced is given by

$$f = \frac{T}{I} r$$

where I = moment of inertia of cross section about the axis of shaft.

2. A weight is on an inclined plane, and is just about to move up the plane by the action of a force whose line of action makes an angle with the plane. Show graphically, or otherwise, how the force required could be determined.
3. A bar of cast iron 12″ long, 1″ wide, and 1″ deep, when loaded at the centre broke with 2,100 lbs. What was the modulus of rupture?
4. Explain exactly the meaning of stress, strain, elastic limit, maximum load, ultimate load, percentage elongation, and percentage contraction. Draw a stress strain-diagram for a piece of steel.
5. Distinguish between rolling and sliding friction. Sketch (*a*) a ball bearing, or (*b*) a roller bearing.
6. In block and tackle with three sheaves in the upper, and two in the lower block, what is the velocity ratio, efficiency, and mechanical advantage?

Mechanical Philosophy. (2.)

[Four *questions and not more are to be answered.*]

1. Sketch and describe forms of hydraulic accumulators suitable for (1) low pressures, (2) high pressures.
2. How would you measure the quantity of water flowing in a stream?
3. Sketch a hydraulic riveter suitable for heavy work.
4. Give the two laws of thermodynamics, and add a short explanation of each.

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5. Explain the advantages in general steam-engine practice, of (1) high speed running, (2) multiple expansion, (3) feed-water heating.
6. Sketch and describe one of the following :—
   (1.) A petrol engine suitable for a motor car.
   (2.) An ordinary oil engine suitable for an electrical generator.

Experimental Science. (1.)

(Inorganic Chemistry.)

[N.B.—*Answer* SIX *questions and no more.*]

1. Mention some of the causes of corrosion of iron and copper when exposed. How can these substances be protected ?
2. Under what circumstances can water be decomposed so as to obtain (i.) hydrogen, (ii.) oxygen in a free state ?
3. Express the combustion process of marsh gas (CH_4) (methane) in air by an equation, and state the volume of each product.
4. What is the difference between quick and slaked lime ? On what actions is the "setting" of a mortar or cement supposed to depend ?
5. What proof can you adduce for the formula NH_3 for ammonia ? How would you extract this substance from sal-ammoniac ?
6. Mention some general characters of "acids." How can hydrochloric acid be obtained and its composition determined ?
7. Compare aluminium and zinc as to (i.) physical properties, and (ii.) chemical behaviour as regards sulphur, oxygen and chlorine.
8. How can the gases nitrogen and oxygen be obtained in a pure state, and how can they be made to combine ?
9. Explain how materials, other than iron, are removed in the puddling and open hearth processes respectively.

Experimental Science. (2.)

(Heat, Magnetism and Electricity.)

[*Not more than* SIX *questions to be attempted.*]

1. What is understood by "electrolysis" ? What class of substances can be electrolysed, and what conditions must be observed ?

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2. What do you understand by the electrical resistance of a wire? State the relation between the resistance, the pressure, and the current. What is the effect of temperature on resistance?
3. Describe a "storage" cell and a "constant" cell, giving details of construction and working.
4. What substances are eminently magnetic? How can a magnet be made and its strength determined?
5. Make a rough sketch of, and state clearly the mode of action of, a simple telephone circuit (transmitter and receiver).
6. A copper and an iron wire are attached to the binding screws of a galvanometer; on twisting the free ends of the wires together and warming the junction an effect is produced in the galvanometer. Describe further what this means.
7. Steam at ordinary pressure is sent through a coil immersed in ice-cold water. One kilo of water is condensed. If the same amount of steam had been brought in contact with ice how much would have melted?
8. Water at 80° C. has to be pumped from one floor to another 25 feet higher Can a common suction pump be used? If not, state why.
9. You have tubes of lead, brass and iron, each 1 metre long, steam is driven through each. What do you observe?
10. What *is* a thermometer? Explain, briefly, how an ordinary thermometer is made and graduated. What would you consider a *perfect* thermometric material, and why?

VALUER, &c., VALUATION OFFICE, IRELAND.

Examination Papers, April, 1903.

Land Valuing.

1. State very shortly the difference in the law of rating land in England and Ireland, pointing out the weaker points in both systems.
2. What circumstances, other than the nature of the soil, would you bear in mind in arriving at the rental value of a farm?
3. Define the following items:—
   "Four course system," "fattening land," "stiff soil," "hungry soil," "cold soil," and "good heart."
4. In valuing land, state the assistance you would obtain from a knowledge of botany and arboriculture.

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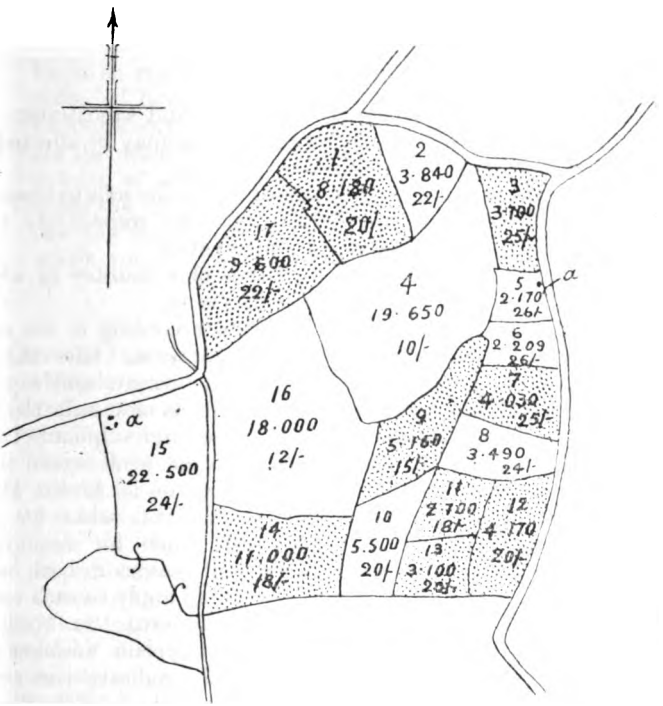
5. What are the current prices of wheat, oats, barley, and hay? (State the market on which your prices are based.)
   What soils are best suited respectively for the cultivation of the above-named cereals, and what would you consider an average yield for each on good land?
6. The farm on the annexed plan has been left by a man to his two sons, the elder of whom is to have the fields Nos. 1 to 13 inclusive.



15 22,500 24/-	Means	Field No. 15 Area 22,500 acres Value 24/- per acre.	Denotes pasture. " arable land.

The original valuation of the land appears in the lists as £160 10s. (which total figure may not be increased on apportionment, 17 Vict., cap. 8), and the buildings at £2 10s.

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The old house and offices, 5*a* on plan, were added to about eight years ago, but were not re-valued; the structural value of these is £140. The younger son has erected a new house and farm buildings on field No. 15, the house costing £120 and the buildings £85.

From the above information and the areas and values per acre given on the plan, show on what valuation each of the two sons will in future be rated.

What exemption, if any, can be made in either case?

Practical Farming.

1. Contrast the weathering of limestones and sandstones, and indicate how soils overlying these rocks may be affected by the weathering processes you describe.

   Would you expect limestone soils or sandstone soils to resemble most the rocks from which they have respectively been derived? Give reasons for your answer.

2. Describe and illustrate the structure of a country in which (*a*) Dip springs, (*b*) Artesian wells occur.

3. Classify the chief phosphatic manures according to the composition of the phosphates found in them. Give the approximate percentage of phosphate present, and say for what particular purpose each manure is most suitable.

4. With nitrate of soda selling at 11s. 9d. and sulphate of ammonia at 11s. 6d. per unit of nitrogen, what would these manures cost if of ordinary composition? At the above prices which of the manures would you select for top-dressing wheat in autumn, and which for manuring potatoes when planting? Give your reasons in both cases, and say how much manure you would apply to each crop.

5. Explain how Lawes and Gilbert estimated the "original manure-value" of feeding stuffs; *or*, explain Voelcker and Hall's method of valuation. Briefly indicate the errors to which such valuations are liable, and say how the figures arrived at should be employed by the valuer.

   The manurial ingredients present in a ton of linseed cake are worth about 60s. What would you expect the manure made from a ton of linseed cake, by cattle fed in boxes, to be worth?

6. Describe the system of culture you would adopt if you wished to grow a first-class sample of brewing barley. Discuss the effects of the preparation of the soil, manuring and seed rate on the quality. In what respects might the culture differ if the object were merely to grow grinding barley?

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7. What treatment would you adopt, in order to ward off or mitigate an attack of "finger and toe" on land in which this disease was common?
8. Estimate the cost of preparing a foul clay loam for sowing down to permanent pasture, and say how you would carry out the work. Specify the grasses and clovers which you would employ, and the approximate quantities necessary per acre.
9. Give suitable winter-rations for—
   (*a*) A two-year old fattening bullock.
   (*b*) A cow giving four gallons of milk per day.

   In each case show the cost per week, by valuing the different foods at market prices, if purchased, and at "consuming rates," if home grown. State the country to which your rations and prices refer.
10. State the usual limits of variation in (*a*) the fat, (*b*) the solids, not fat, of genuine cow's milk.

    Discuss the effects of feeding on the quality of the milk, and cite the results of any experiments on this subject with which you may be acquainted.

Land Surveying. (1.)

1. Describe two methods of prolonging a chain-line beyond an obstacle, such as a house.
2. In what manner is a line that is measured on uneven or sloping ground reduced to its corresponding horizontal length before it can be plotted?
3. A triangular field was measured with a chain that was afterwards found to be one link too long. The sides, as measured, were six chains, four chains and three chains in length respectively. What was the resulting area, and what was the true area?
4. In what manner should the accuracy of a chain be tested?
5. Describe the appliances required for carrying out a chain survey of a large estate.
6. Apart from confusion in the field-book, what are the essential difficulties which tend to produce error in chain surveys, and to render them unsatisfactory?
7. A piece of ground was surveyed by running a chain through it, and by taking offsets to the right to the boundary at 0, 100, 200, 350, 500, 645, 786, 892, and 1012 links, their lengths being respectively 0, 52, 84, 63, 45, 95, 80, 53, and 0 links. What was the area enclosed between the chain and the boundary?
8. With aid of sketches, describe some form of surveying instrument for measuring angles.

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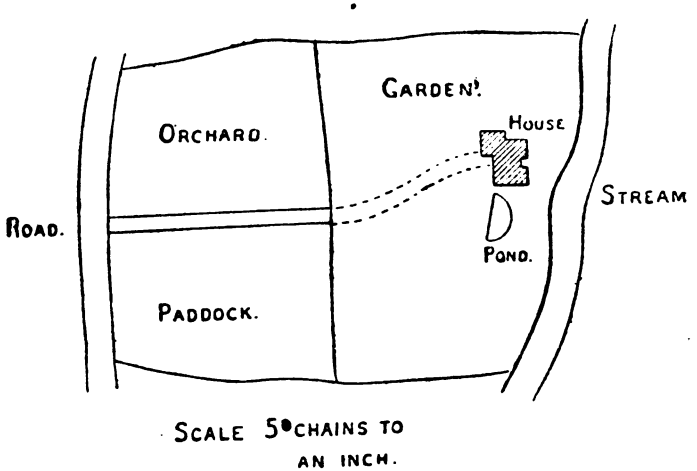
Land Surveying. (2.)

1. From a station, A, within a pentagonal field, the distances to the different corners B, C, D, E and F, were measured and found to be respectively 1469, 1196, 1299, 1203, and 1410 links, and the angles BAC, CAD, DAE, EAF contained by them were respectively 71° 30′, 55° 45′, 49° 15′ and 81° 30′. What was the area of the field?
2. The accompanying plan is considered to represent an actual residential property, of which a survey is required to be made with the chain and tape. Prepare the requisite record of the survey in the form of a field book, and indicate on a plan, drawn to a scale of three chains to the inch, the stations chosen. Ink in and colour the plan.



Architectural Surveying and Valuing. (1.)

1. Give the approximate prices per foot cube for the following, supposing them to be (1) well built, and (2) cheaply built :—
   (*a.*) Brick-built premises with stone dressings and slated roof, ground floor being used as bank offices, and upper floors as manager's dwelling.
   (*b.*) One-storied corrugated iron building, used as creamery, interior matchlined, cement floor.
   (*c.*) Labourer's cottage built of rubble masonry with slated roof.
   (*d.*) Wooden shed (closed) with corrugated iron roof.

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2. Sketch out a ground plan of a country residence with conservatory adjoining, and the usual offices, all of which are situated in close proximity to the house.
3. Price out the following, giving a few details :—
   (*a.*) Asphalte station platform with brickwork facings and stone curb.
   (*b.*) Portland cement floor with floated surface, to Coach house 45′ × 15′, thickness of concrete 6″.
   (*c.*) Hay shelter, curved corrugated iron roof carried on steel uprights, and fitted with gutters and down pipes, 110′ × 24′ × 12′ to eaves.
   (*d.*) Well-built greenhouse, 100′ × 20′ × 8′.
   (*e.*) Chimney shaft (plain brick) to factory, 95′ high, and 10′ square at base.
4. A building with gabled ends and eaves gutters measuring internally 50′ × 24′ is to be covered with a tiled roof. Draw a plan to a scale of $\frac{1}{8}$th inch to one foot showing the position of the trusses, and draw one of the trusses to a scale of $\frac{1}{2}$ inch to one foot.
5. Draw to a scale of $\frac{1}{8}$th inch to one foot, the plan and elevation of a small entrance lodge, containing living room, kitchen, scullery, &c., on the ground floor, and three bedrooms on the upper floor.

Architectural Surveying and Valuing. (2.)

1. Define the following terms :—
   (*a.*) Fee farm rent.
   (*b.*) Net annual value (as applied to Ireland).
   (*c*) Judicial rent.
   (*d.*) Live and dead mains.
   (*e.*) Train miles.
   (*f.*) Statutable deductions.
   (*g.*) What hereditaments are considered in Ireland or England to be (1) partially exempt, (2) wholly exempt, from assessment ?
2. In what way, if any, is the rateable value of premises affected by the presence of water power, of machinery and of advertisement hoardings ?
3. How could you estimate the rateable value of (*a*) a fishery, (*b*) waterworks extending into several parishes, (*c*) a railway station ?
4. Estimate the net rateable values of the following properties :—
   (*a.*) House and garden for which the lessee pays £125 per

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annum, the landlord expending £4, and the tenant £8, per annum on repairs.

(*b.*) House, shop and yard held on a lease which has thirty years to run at a ground rent of £26 per annum, and in turn let to a yearly tenant, who does all repairs, for a rent of £140 per annum.

(*c.*) House, shop and yard held on repairing lease for twenty-one years at £90 per annum, in consideration of a premium of £100 on entry, the tenant also agreeing to lay out £85 on drainage.

(*d.*) A block of buildings let out to weekly tenants, in fourteen equal tenements, gross rental £175 per annum, held under lease at a ground rent of £18 per annum, repairs normal, rates 4s. 6d. in £. Empties amount to about 12 per cent of the gross rental.

(*e.*) Factory and yard held at a ground rent of £60 per annum, buildings recently erected at a cost of £6,000 (the original estimate was £5,300, the extra cost being due to difficulty in finding a proper foundation). Motive power and shafting worth £1,200, other machinery, £860.

5. What are the principal Acts of Parliament relating to the valuation for rating purposes of property in Ireland or England? State, if you are able, the substance of a few of the most important clauses contained therein.

6. There are five different properties each let at a rental of £55 per annum on weekly, quarterly, yearly, three-yearly and long-leasehold tenancies, respectively. Taking the rates at 5s. in £, and the cost of repairs about 10 per cent., what would in each case be the rateable value, assuming the rents to be correct in each case?

ARITHMETIC. (1.)

1. How many words are there on a page of a book, if there are 43 lines on the page and 13 words, on an average, in each line?

2. In a train there are 317 third-class passengers, 129 second-class and 84 first-class. What is the whole number of passengers in the train?

3. A carriage weighs 7 cwt. 3 qrs. Give its weight in lbs.

4. 1,237 half-pence are found in a money box. Give this in £ s. d.

5. $1\frac{3}{4}$ gallons of water are poured into a pail which will hold $2\frac{1}{2}$ gallons. How many more gallons are needed to fill it?

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6. A motor car goes a mile in $3\frac{1}{2}$ minutes. How many miles will it go in an hour?
7. At 9 o'clock in the morning the thermometer stood at 47·7 degrees and by noon it had risen 5·9 degrees. How high did it stand at noon?
8. AB is a line 8·2 centimetres long. On it is marked a length AC 3·56 centimetres long. What is the length of the remaining portion CB?
9. Find, in grams, the weight of 126 shot, each weighing 0·84 grams.
10. How many books each 1·2 inches thick can I place side by side on a shelf 25 inches long?
11. A seventh part of a hectolitre of wine is used daily at dinner at an hotel. Give this in litres to the nearest litre.
12. The difference in time between London and Berlin is 54 minutes. Express this as a fraction of a day (24 hours) in its lowest terms.
13. The distance between two telegraph poles is 0·03 of a mile. Give this distance in yards to the nearest yard.
14. A packet of tobacco weighing 6 kilograms increases in weight 1 per cent. when kept in a very damp place. Give the increase in grams.
15. A child whose height is 1 metre 25 centimetres grows 5 centimetres in a year. What percentage is this of his height?
16. What is spent in a month of 31 days at the rate of £1 3s. a day?
17. What is the cost of 3 gallons 1 quart of whisky at the rate of 25s. for a gallon?
18. If 5 kilograms are equal to 11 lbs., what will be the weight in kilograms of a man who weighs 12 stone? (1 stone = 14 lbs.).
19. You are allowed $1\frac{1}{2}$ hrs. for this paper. If you can work at the rate of 5 questions in 22 minutes, how much time will you have to spare after you have done all the twenty questions?
20. A wall is 30 yds. long, 8 ft. high and 18 inches thick. Give its volume in cubic feet.

ARITHMETIC. (2.)

[*Arithmetical methods of solution are not required. All working must be clearly shown.*]

1. Show that 400 years contain an exact number of weeks. How many weeks are there?
2. On an ordnance map an acre is represented by 1·0036224

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square inches. Find the ratio of the area of the map to the area of the country represented.

3. In four examinations for each of which the total is 100 a candidate obtains an average of 72 marks for the first three examinations, and 80 marks for the fourth. What is his average for the four examinations ?
4. The cost of printing a pamphlet is £150 for the first thousand copies and £5 more for each additional thousand. How many copies at 3d. each must be sold to produce a profit of £80 ?
5. What is a prime number ? Which of the following numbers are prime, 2, 89, 899, 1,001 ?

Subjects for English Composition.

[*You should pay attention to your spelling, punctuation, grammar, and style. Your Composition should fill at least two pages, but it will be valued according to the quality rather than the quantity.*]

Write an essay on *one* of the following subjects :—

Should the Irish language be taught in Irish schools ?

Or,

Is a literary or a scientific education better ?

Or,

Is presence of mind inherited or acquired ?

EXAMINATION PAPERS, July, 1903.

Admiralty, Assistant Surveyor.

Quantities. (1.)

Take off the quantities of a building as shown on the accompanying drawing and in accordance with the following specification :—

Lias lime concrete, stock brickwork in cement, rough cast facing, cement plinth and dressings, ½″ asphalte damp proof course, rubbed York step, Bangor countess slating, close cut and mitred

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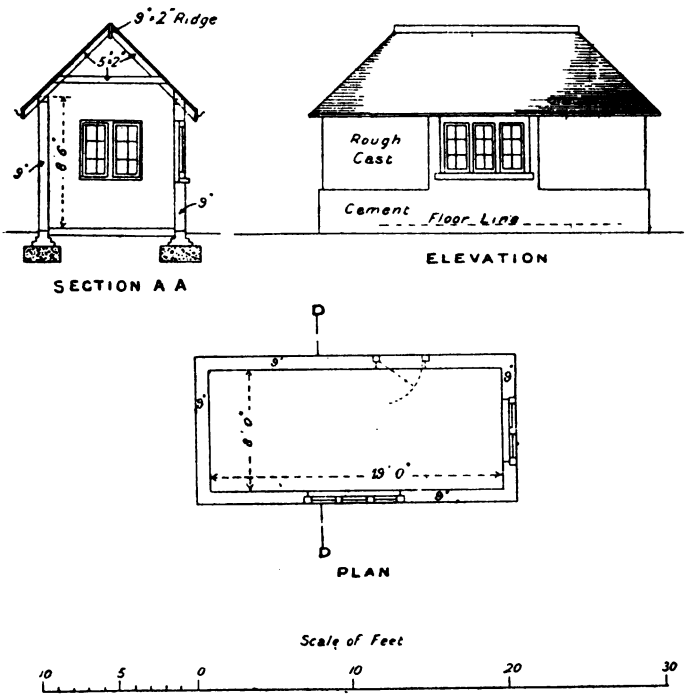
hips, $2\frac{1}{2}'' + \frac{3}{4}''$ slating battens, $\frac{3}{4}''$ roof boarding, Groggon's roofing felt, red tile crested ridge, $1\frac{1}{2}''$ cement paving on 6″ cement concrete bed, fir lintels, 2″ moulded deal casements hung on 3″ brass butts and fitted with brass cockspur fastening and brass stay bar and pins, $4\frac{1}{2}'' \times 3\frac{1}{2}''$ fir frame rebated chamfered and beaded, wide teak sills, $3\frac{1}{2}''$ thick, 2″ deal 4-panel bead flush both sides door 7′ 0″ high, hung with 4″ wrot iron butts, and fitted



with 7″ two bolt three lever mortice lock with strong brass furniture, and two 10″ wrot iron barrel bolts with brass knobs; the plastering Portland cement plain face trowelled for paint; the finishings around openings in Portland cement with rounded angles; 5″ half round C.I. eaves gutters on W.I. brackets, 3″ C.I. rain pipes, 4 lbs. lead soakers to hips; 21 oz. best quality sheet glass; painting K.P.S. and four oils.

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QUANTITIES. (2.)

Square the dimensions and abstract and bill the items on this sheet.

	123 2 1 6 1 0	Exc. surf. trenches and throw out; and Temporarily deposit, return, fill in and ram.	
	123 2 1 4 6	Ddt. R. F. and R.; and Add, fill and cart.	
	123 2 9 6		
	123 2 6	1¾ B.	*Foots.*
	123 2 2 6	1 B.	
	123 2 9	D.P.C. of two courses stout slates, breaking joint, and bedded in ct.	
	102 2 14 6	1 B.	
	21 0 8 6		
	19 0 9 6	2½ B.	*Chy. B.*
	7 2 11 3	3 B. in ct.	*Stack.*
3/	1 6 3 0	1½ B. ddt.	*Fires.*

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QUANTITIES. (2.)

3/	3 6		2″ × ⅜″ W. I. chy. bar caulked and cambd. and bldg. in by Bklr.; and Bar (2) before.
3/	No. 1		Ex. lab. waste and ct. to seg. A. in ct. 2′ 0″ × ½ B. × 1 B.
3/	1 6 1 2		1″ P. ct. floated and trowd. hearth.
3/	No. 1		Ex. lab. and mtls. trimmg. floor jsts., and supplying bds. and fils. spiked to jsts., to rec. 6″ conc. slab 3′ 0″ × 1′ 6″.
3/	3 0 1 6		6″ P. ct. conc. slab for front hearths.
3/	3 0 1 6		1″ P. ct. hearth a, b.
3/	No. 1		Rendg. back of firepl. ¾″ thick in lime and hair mortar.
3/	No. 1		Flue parged with cowdung mor. and cored out at compln.
3/	No. 1		Apprd. plain red Terra Cotta chmy. pots and setting and flaunching in ct.
			Provide 20*l.* for mantel registers and Allow for expenses and profit.
3/	No. 1		Lab. and mtls., setting only iron mantel register to 18″ opening, inclg. the req. fire bks. lumps and clay; and Blacking stove; and (2) and (2) on iron chy. P.

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QUANTITIES. (2.)

3/	2 0 3 0	Ddt. R.F.S. walls ; and Ddt. 2ce distr.
3/	No. 1	M. G. in Par. ct. after fxg. mantel register.
2/	7 0	8″ × 4″ Teak frd. sill to cast. frs. 3ce sunk weathd. check thrtd., 2ce rod. and 2ce grvd.
2/	No. 2	Ends teak sills c. and p. and m. g. ct. reveals.
2/	13 5	5″ × 4″ wrot. a. r. and frd. Dl. Fr. 2ce rebd., check thrtd., grvd. and rod.
2/ 2/	3 6	5″ × 4″ mull. to match.
2/ 3/	1 10 3 0	2″ Dl. mod. casts. in small squares hung at side.
2/ 3/	1 7 2 8	32 oz. sheet glass *in 6.*
2/ 3/	No. 1	Pr. 3½″ W.I.B.
2/ 3/	No. 1	Japd. iron cast. stay bars p.c. 4s. per set and fxg.
2/ 3/	1 10	Lab. to spyd. spy. rebd. and grvd. edge to btm. rail of cast.
2/	6 6 7	1¼″ crosstngd., rebd. and rod., ww., bd. and bearers.
2/	No. 2	N.R.M.E.
2/	6 6	1¾″ × ¾″ Deal bed molding : and ¾″ Nar. spyd. grds.

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QUANTITIES. (2.)

2/	No. 2		R.M.E. to mo.
2/	13 0 6		1″ rod. rebd. and spy., grvd. linings an tongued angles and bckgs.
2/	13 0		Plaster quirk.
2/	13 6		2″ × 1″ Dl. mo. fxd. on outside of ww. frs., scrbd. and inclg. mi. and scrbd. ends.
2/	6 0 3 6		Ddt. R.F.S. walls ; and Ddt. 2ce distr.
2/	127 3 8 6		Add do. ; and Do.
2/ 3/	8 0		Rod. angle in plaster 1″ girth.
	14 0 11 6		L.P.F.S. ceiling.
	23 0 1 6		Do., sloping.
3/	No. 2		K.P.S. and (4) on frs. = (5)
	No. 3		Casement edges.
3/ 6/	No. 2		Sqrs.
3/	7 0 1 0		(5)
	6 6 1 0		

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Estimating and Valuing.

Price the accompanying bill of measured works at London prices. If you are not acquainted with London prices you may use others, stating the district in which they are current. Give the analysis of the prices where the items are marked with an asterisk.

Note.—The prices are not to be extended.

Yards	Feet					£	s.	d.
4,230	—	—	Cube	Excavate for basement not exceeding 6′ 0″ deep and throw out - - -				
7	—	—	„	Do. for pier holes commencing at level of general basement excavation, and not exceeding 3′ 0″ deep below same and do. - - -				
	4,400	—	Sup.	Close boarded planking and strutting to one side of excavation - - -				
*165	—	—	Cube	Cement concrete (1 & 7) in foundations - -				
*1,925	—	—	Sup.	Bed of cement concrete 9″ thick as described, levelled on top and left spade face -				
Rods *262	230	—	Sup.	Reduced stock brickwork in lime mortar (1 & 3) - -				
75	52	—	„	Do. do. in backing to masonry (measured net deductions taken for stonework) - - -				
Yards 202	—	—	„	Extra for face of brickwork worked fair and flat joint pointed for lime-whiting -				
136	—	—	„	Hard stock brick on edge paving grouted in mortar -				
	230	—	Run	Circular cutting and waste on do. - - - -				
	24	—	„	Labour beam filling to one brick wall - - -				
	14	—	„	Extra on fair face for rounded quoin 2¼″ radius in moulded gaults - - -				

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Estimating and Valuing.

					£	s.	d.
Feet 151	—	Run	Rake out joints of brickwork for, and point in cement to flashings - - -				
353	—	,,	Edge 6½″ stone landing cut and pinned in cement -				
	No.	16	Perforations for pipe through average 1½ brick wall and make good facings - -				
	,,	590	Window sills bedded hollow and made up and pointed at completion - - -				
	,,	109	Flues parged with cow-dung and hair mortar and cored out at completion (average length 30′ 0″) - -				
	,,	12	Cast iron double soot doors 10″ × 10″ with frames of approved pattern and building in - - -				
			Best Selected Brown Portland Stone.				
13,529	—	Cube	Stone, including hoisting and setting in mortar (measured net as set) - - -				
342	—	,,	Do. do. in scantling lengths				
			Labours on the foregoing.				
3,775	—	Sup.	Back - - - -				
22,368	—	,,	Plain beds and joints (one for two) - - - -				
34	—	,,	Circular joint (all measured) -				
2,485	—	,,	Sunk beds and joints - -				
1,027	—	,,	Sunk joint circular - -				
11,300	—	,,	Plain work - - -				
204	—	,,	Do. circular - - -				
37	—	,,	Do. elliptical - -				

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ESTIMATING AND VALUING.

	Feet					£	s.	d.
	4,195	—	Sup.	Sunk work - - -				
	980	—	„	Do. stopped - -				
	444	—	„	Do. circular - - -				
	15	—	„	Do. circular circular stopped				
	42	—	„	Do. elliptical - - -				
	7,512	—	„	Molded work - - -				
	6	—	„	Do. do. circular circular -				
	116	—	Run	Plain margin 1″ wide - -				
	2,293	—	„	Do. 1½ wide - -				
	44	—	„	Do. do. circular -				
	12	—	„	Narrow sunk margin in caps and bases - - -				
	191	—	„	Sunk margin 2½″ wide stopped No. 204 stops.				
	18	—	„	Molding 3″ girth - -				
	17	—	„	Do. stopped - - -				
	4,069	—	—	Cement and pebble joggle joint, including pair of V grooves				
Squares *559	80	—	Sup.	Flat boarded centering to concrete floors and strutting or clipping up - - -				
	239	—	„	Centering to segmental or flat soffits - -				
	523	—	Cube	Fir framed in roofs - -				
	98	—	„	Do. do. and fitted to iron -				
	87	—	„	Do. do. and do. and the ends dovetailed to rafters -				
*	72	—	Sup.	1¼″ boarding to flats, edges jointed, prepared for lead and firrings to falls 2½″ thick, and fixing on concrete, all in small quantities in dormer tops - - - -				

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ESTIMATING AND VALUING.

						£	s.	d.
	Feet 204	—	Sup.	$1\frac{1}{4}''$ gutter boards and $2\frac{1}{2}'' \times 2''$ framed bearers - -				
	28	—	Run	$7'' \times 1\frac{1}{4}''$ chamfered fascia and backings fixed with screws -				
		No.	69	Sinkings in deal for soldered dots - - - -				
		,,	2	Draw borings to fir posts 3′ 0″ long for iron bolt - -				
				Wrot Deal.				
	26	–	Sup.	2″ molded fanlights with cross bars and hung at bottom -				
*	30	—	,,	2″ molded centre hung casements including cut beads or moldings on both sides -				
		No.	16	2″ molded fixed sashes in one square and of quadrant shape, size 1′ 2″ × 1′ 11″ (extreme) - - -				
	144	—	Sup.	$1\frac{1}{2}''$ molded and square framed doors, folding in six panels the pair - - -				
	191	—	,,	2″ five panel doors, the lower four panels molded and square framed, the upper panel out for glass - -				
		No.	142	Extra to rails of doors prepared with double tenons at both ends for mortice locks -				
	79	—	Sup.	2″ dwarf fixed framing molded and square framed one panel high - - -				
*	46	—	Sup.	$1\frac{1}{4}''$ cross-tongued and rounded window board and bearers, and scribing at back to stone				
	9	—	Run	$7'' \times 1\frac{1}{2}''$ linings rebated, staff beaded and tongued angles and backings - -				

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ESTIMATING AND VALUING.

Yards					£	s. d.
6,952	—	—	Sup	Render, float and set walls, finished trowelled stucco for paint - - -		
	4,559	—	Run	Molded cornice 9″ girt in gauged stuff - - -		
5,789	—	—	Sup	1″ floated bed in cement and sand (1 and 2) on concrete to receive floors - -		
	1,856	—	Run	9″ Portland cement flush skirting on brick - - -		
				Keene's Cement on and including Portland Cement backing (1 *and* 2).		
	3,659		Sup.	Plain face on brick in narrow widths to reveals, &c.		
	3,254	—	Run	Molded angle 3″ girt and one 2″ return, and including mitres, stopped ends, &c. - -		
Cwts.	qrs.	lbs.				
*2,529	2	14	—	In rolled steel joists of 4″ × 1¾″, 4¾″ × 1¾″ and 6″ × 3″ sections cut to exact lengths as required, and hoisting and fixing at various levels up to about 70′ 0″ above street level by bricklayer - -		
		No.	41	Extra to butt joints of two 4″ × 1¾″ steel joists and ¼″ fish plate, and one ½″ bolt and nut to each side of the joint, and including all holes -		
*252	3	7	—	Milled lead and labour in gutters, flats, flashings, &c. -		
		No.	222	Bossed ends to rolls - -		
		,,	5	Extra labour dressing lead gutter as shoe to discharge into rain-water head - -		
		,,	12	Extra labour and copper nailing to large cesspool (no solder to be used) - -		

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Estimating and Valuing.

						£	s. d.
	Feet 17	—	Sup.	21 oz. fluted glass (three flutes to the 1″), and glazing in squares not exceeding 2′ 0″ super - - -			
	107	—		21 oz. do., do., do. and bedding in wash-leather or black ribbon velvet - -			
	15	—	,,	¼″ British polished plate glass of best glazing quality, and glazing in squares not exceeding 2′ 0″ super - -			
Yards 552	—	—	,,	*Paint two coats of red lead and oil before fixing on iron* -			
5	—	—	,,	*Paint two coats red lead and oil before, and two coats Gay's enamel paint after, fixing on iron* - - -			
				On Wood.			
243		—	,,	Knot with gold size, prime with red lead and oil, stop and paint four additional coats oil colour - - -			
		No.	124½	Dozen squares - - -			
		,,	6	Sash sheets - - -			
		,,	49	Casements (edges only) -			
		,,	9	Frames - - -			
		,,	3	Extra large two light frames			
10,086	—	—	Sup.	Twice distemper a tint on plastered walls - -			
5,908	—	—	,,	Twice distemper cream colour on plaster ceilings - -			
					£		

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Specifications and Contracts.

1. Specify three different kinds of concrete, stating the conditions under which you would use them.
2. Write a Specification of the underpinning of a party wall 2 bricks thick in connection with the formation of a new basement in a London house.
3. Specify the following materials: Portland cement, York stone for steps, fir for carpentry, deal for joinery, cast iron, steel.
4. (*a*). Write a clause for the Preliminary of a Specification, treating of p.cs. and provisional sums and quantities.
   (*b*.) How would you deal with these matters at the settlement of the accounts?

English Composition. (1.)

You go to inspect certain works in progress and notice that some of the brickwork dimensions are not in accordance with the drawings. You write to the contractor for an explanation, and he replies that the dimensions were not fully figured on his drawing, and so had to be obtained by scale; that the clerk of the works did not remonstrate in any way, and that the dimensions in question are unimportant and do not affect the stability of the work.

Write the contractor's letter to you and your reply to his explanation.

Subjects for English Composition.

[*You should pay attention to your spelling, punctuation, grammar, and style. Your Composition should fill at least two pages, but it will be valued according to the quality rather than the quantity.*]

Write an essay on *one* of the following subjects:—

Photography as a hobby.

Or,

The best way of cultivating self-reliance.

Or,

An ideal municipality.

Précis.

After reading the following Report*, write out a concise statement or Précis (1) of the material facts of the case, (2) of the judgment of the Court.

* The Report, which is an ordinary law case, is omitted.

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The object of such a Précis, which should not exceed a page and a half in length, is to enable anyone to master the salient features of the case at a glance without reading the whole Report.

Chain Surveying and Levelling.

1. Lay down all the base lines of the chain survey recorded upon the accompanying extract* from a field book, and plot the detail in pencil to a scale of two chains to one inch, showing the north point in a convenient position on the plan, and drawing a scale of chains (22 yards long) and an equivalent scale of foot links, upon the assumption that a Gunter's link chain had been employed in the field for the measurements.
2. Upon the accompanying plan† indicate in light blue lines such base lines as you would deem necessary for the production of a satisfactory survey required to be made without the employment of an angular instrument.
3. Show in what manner you would ascertain the lengths of any portion of a base line in Question No. 2 which you deemed it desirable to range across the pond situated in the centre of the plan.
4. Compute with the use of an ordinary plotting scale, the area of the enclosure marked A, as well as the area of the enclosure which is marked B and has a hatched boundary; express the result in acres, roods, and poles.
5. Having ranged out a line of section a Surveyor discovers an Ordnance bench mark upon a mile-stone very near the commencement of his line of section, which bench mark is recorded upon the Ordnance map to be 58·35. He sets up his dumpy level in a convenient position and then reads the level staff held upon this bench mark and books the reading as 3·39 feet. With the instrument so set up he reads the staff at 6·50 feet at zero on the line of section, 4·30 feet at 2 chains, 12·50 feet at 3 chains, 13·10 feet at 4 chains, 11·30 feet at 6 chains, and 5·28 feet upon a peg fixed at 7 chains. He then changes the position of the instrument, sets it up level and again reads the staff which the staff holder has retained over the peg at 7 chains. The staff reads now 10·36 feet on this peg. With the instrument so set up, the Surveyor reads the staff 2·59 feet at 10 chains,

* Extract omitted; it is an ordinary field book.

† Plan omitted.

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7·56 feet at 12 chains and 15·90 feet upon a peg at 14 chains. The Surveyor again shifts the level to a new position adjoining the line of section, and having set the instrument level reads the staff which the staff holder has retained over the peg at 14 chains as 0·35 feet. With the instrument in this position, but carefully (as before) revolving the telescope to suit the situation of the level staff, he reads the staff as 4·70 feet at 14 chains 50 links, 10·52 feet at 14 chains 80 links, 13·34 feet at 15 chains 80 links, 13·70 feet at 16 chains, near side of stream, 12·42 feet recording the reading of the staff on the water level, 15·20 feet at 16 chains 5 links bottom of stream, 15·15 feet at 16 chains 9 links, 13·10 feet at 16 chains 14 links far side of stream, 10·11 feet at 16 chains 50 links fair ground, 3·89 feet at 17 chains 20 links and 1·75 feet on a peg fixed at 17 chains 90 links. The Surveyor for the third time shifts the instrument some further distance along the line of section, and having set it up level now reads the level staff held on the peg fixed at 17 chains 90 links as 15·58 feet. With the instrument so set up he reads the staff as 10·75 feet at 18 chains 50 links centre of crosspath, 6·99 feet at 19 chains 60 links, 3·02 feet at 21 chains 40 links and 1·12 feet on the top of a changing peg fixed at 22 chains 70 links. Here the Surveyor for the fourth time shifts the instrument a still further distance along the line of section and again sets it up level. Having done so, he reads the level staff as 6·78 feet on this peg at 22 chains 70 links, 6.11 feet at 23 chains 40 links, 4.95 feet at 23 chains 60 links, 4·59 feet at 24 chains, the end of the section near to which is a bench mark upon a wall which reads at 7·60 feet on the level staff.

Rule a form of level book, naming the columns, and enter therein the above field work. Describe the method of holding a level staff upon an ordnance bench mark as referred to above, and write a brief description of the precautions to be observed in the adjustment of the level, the holding of the level staff and the chainage of distances upon the line of section. If this line of section ran east and west, would you prefer to set up the level upon the north or south side if taking the levels at noon when the sun was shining?

6. Reduce the levels booked in Question 5 and plot this section to a horizontal scale of 2 chains to an inch and to a vertical scale of 20 feet to an inch upon the supposition that a chain of feet links had been employed with the use of a 16 feet level staff in the field for taking the section.

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TRIGONOMETRY.

1. Draw a triangle ABC, having AC 16 cm., ∠ BAC 38° and ∠ BCA 90°. Measure the length of AB, and calculate the value of cos BAC. Compare the value so found with the value of cos 38° given by the tables.
2. Define the *sine* and *tangent* of an angle, and show directly from the definitions that

$$\sin^2 \theta = \frac{\tan^2 \theta}{1 + \tan^2 \theta}.$$

3. Draw carefully a curve showing how the value of $\sin^2 A$ changes as A changes from 0° to 180°.
4. Two sides of a triangle are 5 ft. and 7 ft. long respectively, and the angle opposite to the shorter side is 40°. Find, as accurately as the tables permit, the other two angles and the third side.
5. The summit of a hill, which is known to rise 2,000 ft. above a certain horizontal plane, has an angular elevation of 5° at each of two points in the plane, which are respectively due north and due east of it. Find, correct to the nearest furlong, the distance between the two points of observation.

FRENCH.

Translate into English :—

I.

L'esprit de liberté individuelle se fait jour en Allemagne dans les moindres détails. Trois amis sont assis à la même table, au restaurant par exemple. Ils mangent, ils boivent : on mange et on boit toujours dans ce pays. En France les trois amis boiraient le même vin, mangeraient le même plat, et il y aurait, s'ils étaient bien élevés, assaut de politesse pour trouver le vin qui sera le mieux au goût du prochain. Bien entendu, on ne réussira pas, et l'on finit par ne point s'harmoniser. Ici, c'est bien simple ; chacun boit et mange comme il veut, et tout le monde est content. Après avoir bu et mangé, les Allemands rient d'un gros rire de ventriloque, quand ils ont trente ans....et plus ; avant trente ans, ils chantent. Là est leur côté poétique. Ces lourdauds à tête carrée, aux cheveux blonds en désordre, à l'œil bleu, au pied pesant, ont un sens exquis de l'harmonie. Leur " Vaterland " aussi n'est pas un mot creux comme celui de notre " Patrie." Pas un cœur allemand qui ne se réveille à la première syllabe et qui ne fasse taire tout sentiment personnel pour servir le grand empire.

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II.

A la vie politique viennent de naitre toute une catégorie d'hommes qui certes n'ont point été élevés dans le giron universitaire. Et vous semble-t-il que ces anciens ouvriers ou anciens employés qui n'ont jamais fait de discours écrits, et ignorent la rhétorique, ne sachent pas exprimer leurs idées et défendre leurs intérêts ? Leur éloquence fruste prouve qu'on peut s'en passer, mais elle prouve aussi, cette éloquence qui se laisse aller trop souvent aux pires abandons, que sans la culture littéraire, sans le souci du bien dire qui est comme un souci de dignité personnelle, il ne peut y avoir d'expression haute de la pensée. De là vient l'abaissement de nos mœurs parlementaires. N'est-il pas temps de s'en convaincre et n'est-ce pas un devoir social de donner à ceux dont l'Université forme l'esprit et qui sont l'élite, ou qui doivent être l'élite d'un pays, l'arme de la parole et de réformer l'enseignement dans ce but : faire de tous les élèves des universités non pas des orateurs,—ils seront toujours rares !—mais des hommes capables d'exprimer leur pensée, d'exposer leurs opinions et de défendre leurs convictions, c'est-à-dire des citoyens. Il y a là une simple et ordinaire question d'intérêt, et de défense, mais il doit y avoir aussi un motif plus élevé, celui de relever les mœurs en faisant prédominer l'influence de ceux qui possèdent la culture complète de l'esprit.

Mathematics.

(Mensuration, Arithmetic, Algebra.)

The circumference of a circle is 3.1416 *times the diameter.*

1. Calculate, with as little work as possible, the values of 34203.85×2681.4, $32.25857 \div 2873.2837$ and $\sqrt{.0001564311}$, correct to five significant figures.
2. Compute to two significant figures, the diameter and cross sectional area of a specimen of copper wire, one mile of which weighs 4 lbs.

   N.B.—One cubic inch of copper weighs 0.32 lbs.
3. A hall is 150 feet by 60. The roof is triangular in section, 65 feet high at the centre, and 50 feet high at the sides. How many cubic feet does the hall contain ?
4. A water-pipe is 5 inches in diameter, and the water flows along it at 5 miles an hour. How many gallons of water per day will it deliver ? Give your answer correct to two significant figures.

   A cubic foot of water is 6.22 gallons.

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5. Draw to the scale of 1 inch to the chain, a plan of a field with 4 sides, given the following measurements: AB, 3.61 chains, ∠ CAB 104°, ∠ ABD 127°, ∠ ABC 47.5°, ∠ BAD 28°. From the plan calculate the area of the field to the nearest rood.
6. Solve the equation $x^2 + 19.2x - 2083 = 0$, giving the roots in decimal form to the nearest tenth.
7. The Board of Trade rule for flat stayed surfaces of marine boilers is $p = \frac{c(16t + 1)^2}{s - 6}$ where p is the safe working pressure in lbs. per square inch, t is the thickness of plate in inches and s is the area of plate supported by each stay in sq. inches.

   The "pitch" of the stays, a, is given by $t = 0.009\, a \sqrt{p}$ for steel plates.

   Assume that $s = 1{\cdot}5a^2$, $c = 60$, and find the safe working pressure which may be used with plates 1 inch thick.
8. In a certain experiment the following values of x and y were obtained :—

x - -	1.0	1.7	2.5	3.8	4.2	6	7.8	10
y - -	4.30	5.38	6.63	8.64	9.26	12.05	14.84	18.25

Determine the probable value of y when x was 3, 5, and 8, and exhibit them in a table.

Assuming that there is a simple law connecting x and y, find the law and check your results by means of it.

EXAMINATION PAPERS, MAY, 1903.

OFFICE OF WORKS, ASSISTANT ARCHITECT AND SURVEYOR.

DRAWING. (1.)

(Drawing and Design of Architectural Works.)

NOTE.—*The drawings are to be made on half double elephant paper with a clean firm pencil line. The materials are to be distinguished by the usual tints. All sectional parts are to be coloured and the principal dimensions inserted.*

Subject.

Make a design for a Branch Bank in an important provincial town.

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Particulars.

The site is in the principal Street or Market Square at the corner of a side street.

The available site has a frontage of 50 feet to the main street or square and 100 feet to the side street.

One wall to be a party wall.

Both frontages and back to be treated architecturally.

The Bank entrance to be at the corner or in main frontage.

The buildings to include the following accommodation :—Bank, showing the arrangement of counters and desks; manager's room, &c.; lavatories, &c., for the clerks; strong rooms.

Manager's house, comprising :—Separate entrance, staircase, hall, diningroom, drawingroom, not less than five bedrooms, one dressingroom, one bathroom, lavatories, W.C.'s, &c., kitchen, scullery and usual offices, tradesmen's entrance.

Drawings Required.

(Scale 8″ to 1 inch.)

Basement plan, ground plan, first-floor plan, second-floor plan, one section, two elevators.

Sanitary Engineering.

[*Not more than* six *of the following questions are to be answered.*]

1. Describe the methods usually adopted for the purification of river and spring water before it is supplied for drinking purposes.
2. What is the essential difference in the arrangement for the ventilation of buildings when the currents of air are induced (*a*) by blowers or by fans, (*b*) by Tobin's tubes or other non-mechanical means? Under what conditions are the former appliances most suitable?
3. What bearing has the character of the sub-soil upon the healthiness or otherwise of dwellings?
4. Give a short description of some suitable method of disposing of house drainage and refuse in an unsewered rural district.
5. How many times per 24 hours should the air be changed in a fever ward, and how can this be accomplished with good results, under the varying conditions of external temperature?
6. How are wash-down basins of water-closets flushed, and how is waste of water prevented? What is the minimum quantity of water generally used for each efficient flush?

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7. Make a sketch of the best arrangement you know of for conveying the waste water from a slipper bath to the house drain. Give the areas of the pipes, valve, &c.
8. What conditions most largely effect all systems of ventilating large rooms where numbers of persons assemble?
9. Describe the appliances or apparatus generally used for the disinfection of wearing apparel.
10. Name the most essential points to be provided for, or guarded against, in a school class-room, having regard to the health and convenience of the scholars.

DRAWING. (2.)

(Details of Construction, including Theory of Construction in Architectural Works.)

NOTE.—*The drawings are to be made on half double elephant paper with a clean firm pencil line. The materials are to be distinguished by different tints, and all sectional parts coloured.*

1. A building measuring 45 ft. × 20 ft. of light construction, *i.e.*, 9″ brick walls with an iron roof, and having two division-walls or partitions, has to be erected on a site where the soil is a soft peaty earth with a depth of 40 feet resting on a solid foundation. Draw and give a description of the cheapest secure foundation which can be used under the circumstances, and state any special instructions you would give for its execution.
2. A building for housing machinery has to be erected on a wet soil where the water stands at a level of 2 feet below the surface. It is necessary to have under a portion of it a basement about 25 ft. × 12 ft. (the floor of which is 10 feet below the surface of the ground), which must be absolutely dry and watertight. Make drawings of this basement, giving plan and two sections to a scale of 4 feet to 1 inch, and give descriptive details of the construction, and state the principles that guided you in designing it.
3. Make a drawing to a scale of 4 feet to 1 inch of an underground tank to hold 40,000 gallons of water, and give descriptive details of the construction and the precautions to be taken to insure it being watertight, and state the principles involved.
4. Make drawings to a scale of 4 feet to 1 inch of a brick smoke-stack 70 feet high from the ground. The smallest internal diameter to be 3 feet. The soil is soft for 10 feet below the

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surface, at which level is a bed of solid clay. Flues for two separate furnaces are to be led into the shaft. Give :—

One section.

Two plans and elevation of base and cap.

Give also detail of cap to a scale of 1 foot to 1 inch.

5. The gable end of an old house, 20 feet wide and three storeys high, has three fireplaces one over the other in the centre of this wall, and the chimney breasts project outside 9 inches. There are also windows 4 feet wide on either side of the chimney breast on the ground floor.

It is desired to make a door 4′ 6″ wide on the ground floor in the centre of the wall between the windows in place of the existing fireplace.

Draw and describe on your drawings, indicating the proper names of the various parts, the system of shoring you would adopt, and what provision you would make for permanently carrying out the work above.

Drawing. (3.)

(Details of Construction, including Theory of Construction in Architectural Works.)

[*Rough pencil sketches only, and not finished drawings, are required.*]

1. A building for the purposes of a trade where fire is likely to occur constantly has to be constructed entirely of iron protected by plaster on the inside. Draw to a scale of 2 feet to the inch the plan of one bay, and the transverse section of such a building 30 feet wide and 12 feet to the eaves. Roof ¼ pitch. Give details to ¼ full size of all parts, and show and describe all the methods of construction. Show also how ironwork is fastened to brick or concrete foundation, and draw full-size plan of one angle of the building.
2. Habitable rooms have to be constructed in a roof of a building in a hot climate. The roof is to be constructed of timber covered with tiles. Describe what precautions you would take to keep these rooms as cool as possible, and illustrate your description by a section through part of the roof to a scale of 1 foot to the inch, and state your reasons for the course you adopt.
3. A building measures internally 60 feet long, 20 feet wide, 17 feet high to plate of roof, and is lighted by a lantern light the whole length of the roof. It also has two entrance doors at one end and a large window at the other.

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Show how you would heat this by means of hot water, indicating the position, size and length of pipes or radiators, the details and arrangement of each part, the reasons or calculations which guided you, and the principles involved.

4. What precautions are to be observed in selecting, laying and running the pipes for the supply of water and gas to and in a building? Are they both laid on the same principles, and if not, what is the difference?
5. Give full description of the various methods (patent or otherwise) now available or adopted for casing or otherwise rendering the internal woodwork of buildings impervious to fire.
6. Give a list of the various paints now used for all purposes inside and outside buildings, and describe accurately the materials of which they are composed and the methods of mixing and using.

Use and Properties of Materials.

[*The Candidate is not to attempt more than* six *of the following questions.*]

1. What are the characteristic properties of good bricks, and how do you ascertain them?
2. When inspecting bricks, what defects should you look out for?
3. Describe the chief characteristics of good building stone and how you ascertain them. State also the probable defects.
4. Which stones are most liable to atmospheric disintegration, and under what conditions?
5. What are the differences in the properties of Roman cement, Portland cement and blue lias lime? For what purposes would you use each of these materials?
6. Summarise the headings of a specification for steel required in the construction of girders, stating the required tests.
7. What properties and tests would you specify for cast iron to be used for columns?
8. Describe three distinct classes of timber and the purposes for which each is best adapted.
9. Describe three different kinds of pavement for a street footpath, and state the advantages and disadvantages of each.

Surveying and Levelling.

1. Upon the plan given draw in pencil the base lines you would require to chain upon the ground, in order to make and plot a complete survey of the site represented, without the aid of angular instruments.

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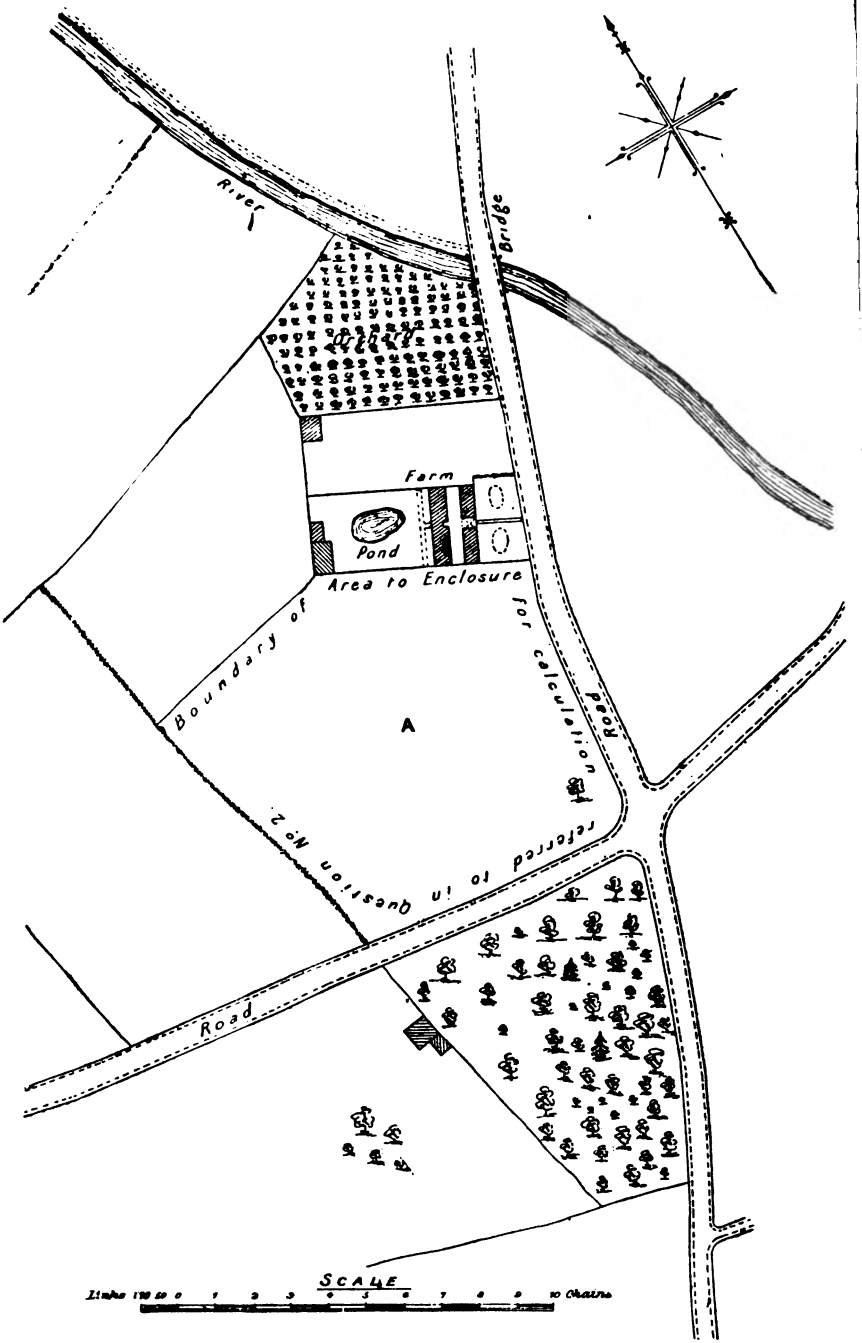
OFFICE OF WORKS. ASSISTANT ARCHITECT AND SURVEYOR – MAY 1903.

Surveying and Levelling

Question No 1.



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2. Compute the area of the enclosure marked A shown upon this plan, using an ordinary plotting scale of 3 chains to 1 inch for the purpose, and give the result in acres, roods and perches.

3. From the following field notes lay down the survey lines and plot the details to a scale of three chains to one inch. (Notes omitted.)

4. Make up the following extract from a page of Level book, filling in the columns headed rise, fall, and reduced levels, and show, in the usual way, that the levels are correctly reduced to a common datum.

Back Sight	Intermediate	Fore Sight	Rise	Fall	Reduced Levels	Lengths	Remarks
3·71					117·94	B.M.	Bench mark on side of
	5·06					0	road in wall opposite
9·40		7·88				200	lamp-post near half-way
	10·20					375	house at 139 ft. from milestone shown on plans.
	12·30					398	Centre of cross road.
3·87		13·89				414	
2·63		11·71				426	
13·62		12·41				433	Fence crosses at 437.
	8·95					450	
4·47		0·85				475	
	2·99					—	Temporary bench mark
6·72		5·06				510	lower hinge of gate to Wood Lodge.
	7·25					—	On edge of ditch.
	8·36					512	Bottom of ditch.
	4·59					516	Stump on top of bank.
		5·12				524	On fair ground.

5. Plot the section derived from the levels furnished by Question 4 to a scale of 40 feet to 1 inch horizontal measurement and to a scale of 10 feet to 1 inch vertical measurement, selecting a convenient height for the datum line, upon the assumption that a chain of 100 foot links has been employed with the aid of a 14 ft. level staff, and show both these scales neatly drawn, and described upon your sheet of drawing paper which contains this section.

6. How is the sensibility of a dumpy level determined, and how are the temporary adjustments effected at each setting up of the instrument? Show also, by the aid of a sketch, how the collimation may be tested and corrected.

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7. In plotting the plan in Question 3 to a scale of 3 chains to one inch, upon the supposition that a chain of 100 short links, measuring altogether a length of 22 yards as used in railway work, had been employed for the field work, how much larger is the area of the ground than that of the plan? If it should be discovered after plotting the survey that a chain of foot links instead of a (so-called) Gunter's chain had been used in the field, how will this consideration affect the statement for the true area?

SPECIFICATIONS.

1. Specify concrete for ordinary foundations; for underpinning; for fire-resisting floors.
2. What are the different bonds used in brickwork? Illustrate by sketches.
3. Specify a queen-post roof truss of 35′ 0″ span, giving the scantlings of the timbers.
4. Specify a deal, lead-lined cistern to hold 400 gallons of water, with overflow and waste pipes.

QUANTITIES AND ESTIMATES.

Roughly take off the quantities and prepare an approximate estimate for an addition to a building as shown on the accompanying drawing* and in accordance with the following specification:—

Stock brickwork in lias lime mortar, red Ruabon facings, ½″ asphalte damp proof course, red Terra Cotta louvred chimney pots, 4″ rubbed Portland stone window sills, rubbed York steps, 6″ ditto templates, countess slating, 2¼″ × ¾″ slating battens, ¾″ roof boarding, inodorous felt, 1½″ pitch-pine block flooring, 3½″ × 1¼″ deal splayed skirting, 2¼″ deal moulded skylights, 2″ moulded casements, 4½″ × 3″ fir rebated and moulded frames with teak sills, 2¼″ deal moulded both sides door, 2″ moulded linings, 3½″ × 1¼″ moulded architraves, Parian cement plain face on walls, fibrous plaster ceiling, 3½″ cast-iron rain-water pipes with plain heads, &c., 4 lbs. lead soakers, 5 lbs. flashings and aprons, 26 oz. seconds sheet glass in doors and windows, painting prime and 4 oils.

*Drawing omitted.

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EXAMINATION PAPERS, JANUARY, 1901.

OFFICE OF WORKS—ASSISTANT SURVEYOR.

DRAWING (1.)

(Drawing and Design of Architectural Works.)

NOTE.—*The drawings are to be made on half double elephant paper with a clean firm pencil line. The materials are to be distinguished by usual tints. All sectional parts are to be coloured and principal dimensions inserted.*

Subject.

Make a design for a country parsonage with all its necessary accessories.

Particulars.

The site may be assumed to be practically level.

Buildings to stand in fenced grounds, with the necessary various entrance gates, stables, outhouses, &c., all of which are to be shown on block plan only.

In order to give an idea of the scale and type of the buildings required, the following details of accommodation and approximate areas of the principal apartments are suggested. All subsidiary accommodation to be in proportion.

Basement.

Wine cellar, beer cellar, meat larder, dairy (optional).

Ground Floor.

Kitchen, about 260 ft. super.; scullery, about 90 ft. super.; 2 larders, china closet, store room, knives and boots, brushing, lamps, wood, coal, men's w.c., maids' w.c., kitchen yard, tradesmen's entrance, luggage entrance, back stairs, dining room, about 350 ft. super.; drawing room, about 450 ft. super.; morning, or school room, about 300 ft. super.; library or study, about 225 ft. super.; parish room, about 325 ft. super.; main staircase, hall, vestibule, hats and cloaks, w.c. and lavatory, serving room, porch.

First Floor.

Day nursery, night nursery, 4 bedrooms, 2 or 3 dressing rooms, bath room, with lavatory, w.c.

Second Floor.—To be partly in roof.

Two good bedrooms, servants' bedroom, servants' bath, servants' w.c., box room, tank room, access to roof.

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Drawings Required.

(Scale 32 ft. to 1 inch).

A block plan of site and general arrangement of buildings, showing drainage and all entrances, paths, &c.

(Scale 8 ft. to 1 inch.)

Of house only :—Basement plan, ground floor plan, first floor plan, second floor plan, with lines of roof ; front elevation, back elevation, section back to front through staircase.

DRAWING. (2.)

(Detail of Construction, including Theory of Construction, in Architectural Works.)

NOTE.—*The drawings are to be made on half double elephant paper with a clean firm pencil line. The materials are to be distinguished by different tints, and all sectional parts coloured.*

1. Show by drawings to scale what precautions you would take to ensure a perfectly dry basement in each of the following soils :—
   i. Solid wet clay on the slope of a watershed.
   ii. Drift gravel near a tidal river where the water rises and falls with the tide.
   iii. Water-bearing chalk.
2. Draw a Section of an external hollow wall to a country house three stories high, and show—
   How the joists are carried ;
   How the walls are tied together and what bond is used ;
   How angles are built ;
   How the window and door openings and flues are managed ;
   How the arches are turned ; and
   How you would provide for any water which may pass through the outer section of wall.
3. Draw $\frac{1}{8}$ full size, and describe by notes on drawings the various methods of laying and fixing—
   i. Plain tiles ;
   ii. Ladies slating.

   Also indicate the meaning of, or illustrate, the following terms :—

   Lap ; gauge ; pitch ; nibs ; holes ; barge course ; double eaves ; raking edges ; tile and half ; half slating ; tile pins ; bedded ; pointed ; torged.

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4. Make detail to $\frac{1}{2}''$ scale of wooden staircase with three sets of flyers, 12, 4 and 8 respectively, with 4 ft. clear going and close strings. Show construction clearly, and give details $\frac{1}{4}$ full size.

Drawing. (3.)

(Details of Construction, including Theory of Construction, in Architectural Works.)

Note.—*The drawings are to be made on half double elephant paper with a clean firm pencil line. The materials are to be distinguished by different tints, and all sectional parts coloured.*

1. Make drawings to $\frac{1}{2}''$ scale of a queen post truss carrying a tiled roof of 45 degrees pitch over a building 30 ft. between walls :—
   1 transverse section of building.
   1 longitudinal section of one bay only.
   Details $\frac{1}{4}$ full size of all joints and parts, including ironwork, if any.

   Figure all sizes, show by what process you arrive at them, and give all figures of calculation.
2. A steel stanchion stands under and supports the centre of a girder 60 feet long, which carries a warehouse wall 18 ins. thick and 40 feet high, which takes the girders (18 ft. span) of four fireproof floors constructed of iron joists and pebble concrete 8 ins. thick, which floors are to carry a load of 2 cwt. per foot super.

   The base of the stanchion is 2 ft. square. This is to be carried by a brick pier 10 ft. high with stone template on top, and footings, with concrete under same resting on London clay.

   Make drawings (plan, elevation and section) to $\frac{1}{2}''$ scale of this pier, with its template, footings and concrete, and give your calculations, and accurately specify the material which you employ.
3. The usual formula for calculating steel beams is $W = \frac{c\ a\ d.}{L}$

   Draw detail of girder described in the last question to quarter full size, giving your calculations in full.
4. An asylum with 300 inmates has to be supplied with water. Draw to a scale of $\frac{1}{2}''$ to the foot a cast iron tank to hold three days' supply for the whole establishment, to be fixed in a tower 60 feet from the ground.

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Give the size of communication or supply pipe from main and of service pipe, and state the pressure per square inch on a valve placed in the service pipe from tank at the ground floor level.

Use and Properties of Materials.

1. What general principles should be observed in the construction of the walls of houses—
   (*a*) When built of bricks?
   (*b*) When built with stone?
2. How would you detect inferior mortar? Describe the composition of mortar, and state how it should be made to ensure first-class work, and how is it generally made in inferior work.
3. What tests should be applied to Portland cement in order to ensure the rejection of all inferior material? Give the reasons for each test.
4. What woods are suitable for common work and for first-class work in staircases, floors, skirtings, doors, &c., and in partially exposed work, such as window-cills, barge-boards, &c.?
5. Name the different kinds of glass used in building, and state how you would identify and select each kind of glass.
6. Name some of the most noted slate-quarries in the British Isles, and describe the characteristics of the best slate for roofing purposes. State how you would test the quality of roofing slate.
7. What metals are chiefly used in building construction? Describe the appearance and the distinguishing features of each kind of metal, and the purpose for which it is used.
8. Name a few of the building stones that you are acquainted with. Describe the character and general appearance of each. When the stone is worked at the quarry, what precautions should be taken to ensure the rejection of all inferior stone?

Specifications.

Write a specification in all trades for the conversion of an existing shop front in a London street into a front for a Public Office, as shown on the accompanying drawing.* The descriptions of the quality of materials need not be in great detail.

* Drawing omitted.

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Quantities and Estimates.

Take off quantities and prepare an approximate estimate for the conversion of an existing shop front in a London street into a front for a Public Office, as shown on the accompanying drawing.*

Sanitary Engineering.

1. What velocities are necessary in sewers, when running ¼ full, in order to prevent deposit—(*a*) in the sewers of towns where the separate system is strictly enforced; (*b*) in the sewers of towns where drainage from the surface of the streets is admitted into the sewers?
2. Describe the action of an intermittent flushing-tank worked by a syphon and fed by a continuous dribble of water. Illustrate your answer with a sectional sketch of the syphon.
3. Describe the methods of heating buildings by (*a*) high and low pressure hot water; (*b*) steam; (*c*) hot air.
4. What are the chief points to be kept in view when considering the ventilation of buildings? Describe any method or methods of ventilating buildings that you are conversant with. To what causes are the failures to obtain desired results generally due?
5. Under what conditions are rivers which flow through thickly populated towns likely to affect the health of residents in their immediate vicinity?
6. Sketch a section of a water-closet and its connecting pipes suitable for use—(*a*) in a cottage yard; (*b*) on an upper floor of a town mansion. Describe briefly the type of closet you would use in each case, and its necessary adjuncts.
7. Name, describe, and sketch the joints used in the plumbing trade.
8. What conditions do you consider essential in a complete system of house drainage?

Surveying and Levelling.

1. Describe different appliances for measuring lengths in the field. A line was measured with a chain that was afterwards ascertained to be one link too short, and was found to be 10·36 chains long. What was its true length?

* Drawing omitted.

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2. With the aid of sketches describe the construction and method of use of *one* of the following instruments: (1) box sextant, (2) optical square, (3) prismatic compass.
3. A recreation ground was surveyed by running a line through it from end to end. From the chain, offsets were taken at right angles at regular intervals of 50 links to the fence, the lengths of the offsets measured in links being respectively 30 (at the starting point), 38, 61, 50, 85, 80, 40, 60, 69, 48 and 19. What was the area included between the chain and the fence?
4. What are the methods usually employed for copying, enlarging, and reducing plans?
5. Work out the following series of levels, and show how you can check the results:—

Distance Links	Back Sight	Intermediate	Fore Sight
35	2·95	3·99	—
90	—	4·90	—
125	—	3·99	—
165	—	3·08	—
220	—	1·07	—
245	—	1·88	—
295	—	5·00	—
335	—	5·52	—
400	—	1·23	—
420	—	—	0·58
455	8·20	7·30	—
515	—	6·50	—
580	—	2·08	—
635	—	1·81	—
740	—	—	1·01

COUNTY SURVEYORS' EXAMINATION (SEPT., 1898).

PART I.

TRIGONOMETRY.

1. If a straight line OP, originally coincident with OA, revolves in a plane about the point O, as it passes through the position in which AOP is a right angle the tangent of the angle AOP changes abruptly from an indefinitely great positive quantity to an indefinitely great negative quantity. Why is this?

If sin 3A = 1, and A is less than 180°, show that A may be either 30° or 150°.

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2. Prove that—

$$\tan(A + B) - \tan(A - B) = \frac{\sin 2B}{\cos(A + B)\cos(A - B)}.$$

3. Find the sine and cosine of 22° 30′ without using mathematical tables.

ABC is an isosceles triangle, the angles at A and B being each 22° 30′; and AD is drawn at right angles to AC, meeting BC produced in D. If the length of AB is 2 inches, find the length of BD to the nearest hundreth of an inch. (For this part of the question you may use mathematical tables.)

4. Prove that—

$$\log^e\left(\frac{x}{y}\right) = \log^e x - \log_e y, \text{ and that } \log_{10}\left(\frac{\sin x}{\sin y}\right)$$
$$= L \sin x - L \sin y.$$

5. Prove the following formulæ for any plane triangle ABC :—

(1.) $a = b \cos C + c \cos B$;

(2.) $\sin^2\frac{A}{2} = \frac{1}{bc}(s - b)(s - c)$.

6. In the triangle ABC, $\frac{a}{b} = \frac{7}{6}$, and C = 60°, find A and B to the nearest minute.

7. A vertical tower stands on the side of a hill; a road, rising at an inclination of 1° 30′ to the horizon, leads straight up to it; and at a point in the road, 100 feet from the base, the tower subtends an angle of 45°. Find the height of the tower to the nearest foot.

Geometrical Optics.

1. State the laws of refraction of light. How is it established that the refraction coefficient from a medium B to a medium C is the ratio of the coefficient from air to B and from air to C?

2. A small piece of glass, half of which is silvered, is held horizontally at a vertical height h above the edge of a clear stream; a person looking into the glass from below sees the sun coinciding with its image formed by rays that have been reflected at a reflecting surface lying horizontally at the bottom of the stream, in mid-stream. The breadth of the stream is known to be $2c$; prove that its depth is

$$\sqrt{\mu^2 - \cos^2\theta}\,(c \sec\theta - h \operatorname{cosec}\theta),$$

where μ is the index of refraction for water, and θ the elevation of the sun.

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3. Prove that the deviation of a ray of light refracted through a prism is on the whole away from the edge.
4. Explain the origin of the bright curve sometimes seen on the surface when a cup of tea, nearly full, is standing in the sun, drawing a diagram to explain your answer.
5. Prove, for reflection at a spherical mirror, the formula

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{r},$$

in which distances are measured from the centre of the mirror, explaining the convention of signs. Describe a method whereby this result can be practically verified.

6. If a, a' be the diameters of a small luminous object and its image, after direct refraction into a medium of index μ, prove that

$$\frac{a}{a'} = 1 + \frac{\mu - 1}{r} u,$$

where r is the radius of the face of the medium, and u the distance of the object before this face.

7. Draw a diagram to illustrate the use of a magnifying glass of two lenses. What is meant by saying that a magnifying glass is achromatic?
8. Give a short account of the theory of spectrum analysis.

Geometry and Algebra.

[*In the first* THREE *questions ordinary abbreviations may be used, but the method of proof must be geometrical.*]

1. If a side of a triangle is produced, the exterior angle is equal to the two interior and opposite angles; and the three interior angles of every triangle are together equal to two right angles.

   If the side BC of a triangle ABC is produced both ways, and the bisectors of the exterior angles so formed are parallel to AC and AB respectively, show that the triangle is equilateral.

2. Prove that the difference of the squares on any two straight lines is equal to the rectangle contained by the sum and difference of the lines.

   Show also that, if the rectangle contained by the sum and difference is equal to the rectangle contained by the lines themselves, the lengths of the lines are as $\sqrt{5} + 1 : 2$.

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3. The straight line which is drawn at right angles to the diameter of a circle at its extremity touches the circle.

If from a point O, equidistant from two parallel straight lines, any two straight lines, OA and OB, are drawn at right angles to one another, and cutting the parallels in A and B; show that AB touches the circle described with centre O to touch both the parallel straight lines.

4. Find the highest common factor of

$$x^3 + y^3 + z^3 - (y^2 + z^2)\,x - (z^2 + x^2)\,y - (x^2 + y^2)\,z + 2xyz$$

and

$$x^3 + y^3 - z^3 - (y^2 + z^2)\,x - (z^2 + x^2)\,y + (x^2 + y^2)\,z - 2xyz.$$

5. If

$$\left(\frac{1-x}{1+x}\right)^{\frac{1}{2}}\left(\frac{1-y}{1+y}\right)^{\frac{1}{2}} + \left(\frac{1-y}{1+y}\right)^{\frac{1}{2}}\left(\frac{1-z}{1+z}\right)^{\frac{1}{2}} + \left(\frac{1-z}{1+z}\right)^{\frac{1}{2}}\left(\frac{1-x}{1+x}\right)^{\frac{1}{2}} = 1,$$

show that

$$1 - x^2 - y^2 - z^2 = 2xyz.$$

6. Form the quadratic equation in which the sum of the roots is equal to p, and the sum of their reciprocals to $\frac{1}{r}$.

7. Solve the equations

(1) $3x^2 - 12x - 7 = 14\sqrt{x^2 - 4x - 5}$;

(2) $x(5y + x) = 2y(5x - 3y) = 2\frac{2}{3}$.

8. Find the square root and the cube root of

$$(x^3 + 1)^2 - 6x(x^2 + 1)^2 + 15x^2(x + 1)^2 - 40x^3.$$

9. M being the middle term of an arithmetical series of $2n + 1$ terms, show that the sum of the series $= (2n + 1)M$.

If a clock, beginning to go wrong at noon on a certain day, loses 1 sec. in the first hour, 2 secs. in the second hour, 3 secs. in the third hour, and so on; what will be the time by the clock at noon the next day?

10. If N is the nth term, and R the rth term, of a geometrical series, find the first term and the common ratio.

11. If $a : b = b : c = c : d$, show that

$$\left(\frac{a^2 + b^2 + c^2}{b^2 + c^2 + d^2}\right)^3 = \left(\frac{a}{d}\right)^2.$$

12. Find the 5th, 7th, and 9th terms in the expansion of $(1 + x)^{12}$ by the Binomial Theorem.

Find also the value, correct to six places of decimals, of $(1-x)^{-\frac{1}{2}}$ when $x = 0{\cdot}025$.

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MATHEMATICS.

(Differential and Integral Calculus.)

[*Full marks may be obtained for about* three-quarters *of this paper.*]

1. Find the limit to which the following functions tend as x approaches zero :—

$$(1)\ \frac{\sin^2 x}{x}; \qquad (2)\ \frac{x - \frac{x^2}{2} - \log_e(1+x)}{(1-\cos x)^{\frac{3}{2}}}.$$

2. Explain the phrase "differential coefficient of one quantity with respect to another."

   A sphere is constantly changing its size, but so as always to retain its shape. Find the differential coefficient of its volume with respect to its surface at the instant when its radius is equal to unity.

3. Differentiate with respect to x :—

$$(1)\ \left(x + \frac{1}{x}\right)^x; \qquad (2)\ \sinh^{-1}\frac{ax+b}{\sqrt{ac-b^2}}; \quad (3)\ \tan^{-1}\sqrt{\frac{x^2-a^2}{a^2}}.$$

   Find the nth differential coefficient with respect to x of

   (1) $\sin x$, (2) $\sin x \cos x$.

4. Show how the Differential Calculus may be applied to find the turning values (maxima and minima) of a continuous function of a single variable.

   Find the turning values of $x^5 - 5x^4 + 5x^3 + 1$, and discriminate between them.

5. Show that the tangent at any point of the curve $r = ae^{m\theta}$ makes a constant angle with the radius vector to the point. Hence show that in the case of this curve the radius of curvature is $\frac{ds}{d\theta}$ and find it in terms of r.

6. Find the following integrals—

$$(1)\int(x\log x)^2 dx, \quad (2)\int\frac{dx}{(x^2-a^2)(x^2-b^2)}, \quad (3)\int\frac{dx}{(1-x)^2(2-x)^2}.$$

   Given that $\int\frac{dx}{\sqrt{a^2-x^2}} = \sin^{-1}\frac{x}{a}$, find $\int\frac{dx}{(a^2-x^2)^{\frac{3}{2}}}$.

7. Evaluate the definite integrals.

$$(1)\int_0^{\frac{\pi}{2}}\sin^{2m}x\,dx, \qquad (2)\int_a^b\frac{dx}{\sqrt{(x-a)(b-x)}},$$

$$(3)\int_{2a}^{2a}dx\,\tan^{-1}\sqrt{\frac{x-a}{a}}.$$

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8. Explain how the area of a curve may be found by the Integral Calculus.
   Illustrate by finding the area common to the curves $x^2 = py$, $y^2 = px$.
9. Trace the curve $r^2 = a^2 \cos 2$ and find its area.
10. A circle of radius c revolves round a line in its own plane at a distance d from the centre: find the volume of the solid generated after a complete revolution ($d > c$).

Mechanical Philosophy.

(Statics and Dynamics.)

1. Prove that the resultant of two forces represented in all respects by the lines OA and OB, which are at right angles, acts along the diagonal of the rectangle CAOB.
   If the forces are 5 and 12 lbs. wt., what is the magnitude of their resultant?
2. Determine the resultant of two unlike parallel forces, in magnitude and direction, and show that if the points of action and magnitude of the two forces are given, the resultant passes through a fixed point.
   Define the centre of a mass of a body, and prove that every body has a centre of mass.
3. Prove that three forces cannot keep a body in equilibrium unless they lie in one plane and are either parallel or meet in one point.
   A smooth rod rests with one end in a fixed hemispherical bowl, and the other end projecting over the edge, at an angle α to the horizon. Prove that its centre of gravity is at a distance D $\cos 2\alpha \sec \alpha$ from its lower end, D being the diameter of the bowl.
4. Define the moment of a couple, and prove that two couples, of equal but opposite moment, acting in the same plane on a rigid body, will balance one another.
   ABC is a rigid triangular lamina, and D is the middle point of BC. Determine the resultant of four forces represented in all respects by BC, CA, AB, AD.
5. Describe the Danish steelyard, and show how to graduate it.
   If the steelyard was originally correct, but has been eaten away by rust so that its weight is only e times its original value, its centre of mass being the same, what is the true weight of an article of apparent weight W?

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6. Define acceleration, and prove, for motion in a straight line with uniform acceleration f, that the distance described in time t is $ut + \frac{1}{2} ft^2$, u being the velocity at the beginning of the time t.

   A smooth body is guided from a window to the ground by being allowed to slip along a smooth board. Prove that the time in which it reaches the ground varies as the cosecant of the inclination, but that its speed on reaching the ground is always the same.

7. Weights P and Q are connected by a light flexible string over a smooth fixed pulley. Determine the acceleration with which they move when allowed to hang freely.

   If a third weight R is attached to Q by a string of length c, and at starting Q and R are lying together on a table, vertically under the pulley, determine the velocity of the three weights just after R has been pulled into motion, P being greater than Q.

8. Give Newton's third law of motion. Enumerate the forces in action on a cart pulled by a horse along a rough horizontal road with uniform velocity; and find the pull of the horse in terms of them.

9. For shots fired with a given velocity, determine the direction of projection so that the range on an inclined straight road through the point of projection may be the greatest possible.

   A shot is fired horizontally from the top of a tower h feet high with the velocity it would acquire in falling to the bottom of the tower. Find its range on the ground, the resistance of the air being neglected.

10. A mass m is placed on a smooth inclined plane of mass M, and inclination α, which can slide on the smooth table upon which it stands. Find the accelerations in the motion which ensues.

MECHANICAL PHILOSOPHY.

(Hydrostatics, Hydraulics, Pneumatics, and Heat.)

[N.B.—*Not more than* EIGHT *questions to be answered.*]

The mass of a cubic foot of water may be taken as $62\frac{1}{2}$ *lbs., and the value of* π *as* $\frac{22}{7}$.)

1. Prove that the resultant pressure on a body immersed in a fluid at rest is equal to the weight of the fluid displaced by the body.

   A closed hollow vessel weighs 4 ounces, and displaces, when completely immersed, a quart of water. Find what quan-

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tity of water must be placed inside it in order that, when completely immersed in water, it may neither rise nor sink, assuming that the weight of a gallon of water is 10 lbs.

2. Two vessels of equal size are brimful of water. In one a piece of iron weighing 10 lbs. is gently immersed, and in the other a piece of zinc. If the amount of water which flows over be the same in each case, find the weight of the piece of zinc, having given that the specific gravity of zinc is 7·2, and that of iron is 7·8.

3. The centre of pressure on a plane surface immersed in a fluid being given, determine the centre of pressure after the surface has been moved parallel to itself to a position of greater depth than before.

A rectangle measuring 2 feet by 3 feet is immersed in water, so that the shorter sides are horizontal, the upper edge being in the surface. If the rectangle remain fixed, while water is poured into the vessel so that the surface is raised a foot, find the depth of the centre of pressure after the operation.

4. Describe the essential parts and the mode of working of a common lifting-pump.

Find the tension of the piston-rod of a lifting-pump when the piston is 20 feet above the water in the reservoir and 9 inches below the spout, the diameter of the pump-barrel being 5 inches. The tension is required when the piston is at rest, and the upper part of the barrel full to the spout.

5. If the receiver of a single-barreled air-pump have a cubic content of 1,000 cubic inches and the cubic content of the barrel be 66⅔ cubic inches, find how many strokes will be required to reduce the pressure in the receiver by one-fifth.

6. State the relation between the pressure, volume, and temperature of a given mass of gas.

A certain mass of gas at 15° C. is contained in a cylinder of which it occupies a length of one foot. Its temperature is raised 20° centigrade without change of pressure. Find what length it will then occupy.

7. Determine the velocity of outflow of water from a reservoir through an aperture at a given depth below the surface.

A circular pipe, 2 inches in diameter, is connected with a reservoir so placed that the pressure at the lower end when closed is 70 lbs. on a square inch. Find what mass of water flows out in ten minutes when the pipe is opened, the pressure of the atmosphere being 14½ lbs. on a square inch. Friction is to be neglected.

8 Describe some form of apparatus for determining the mechanical equivalent of heat.

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Find the amount of work which must be done to melt and raise to the boiling point a hundredweight of ice. [The latent heat of fusion of ice is 144, and the numerical measure of the mechanical equivalent of heat may be taken as 772 in Fahrenheit units.].

9. Explain what is meant by adiabatic and isothermal lines, and show that the efficiency of an elementary heat engine varies as the range of the temperature of the fluid used to drive it.

Inorganic Chemistry.

1. What causes tend to vitiate the air of a dwelling room? How may the air of a room be maintained in a state of purity without causing draughts?
2. Describe, briefly, the manufacture and purification of coal gas. What impurities are objectionable to the consumer?
3. What are the causes of hardness of water? How is the hardness of a water estimated? Give details of processes available for the softening of water.
4. Give some account of the structure of a flame. Under what circumstances is a luminous flame obtained? Give some account of the causes of luminosity of flame.
5. Show how you would burn coal gas in order to obtain the maximum illuminating value from it? What is meant by sixteen candle power gas?
6. Give an account of the chemical processes involved in the rusting of iron. How are iron surfaces protected from rusting while in contact with (*a*) air, (*b*) water?
7. What is meant by the "calorific value" of a fuel? What points are to be attended to in selecting coal for use in steam generation?
8. Describe the manufacture of wrought iron. Make a comparison of the chemical and physical properties of (*a*) white and grey pig iron, (*b*) wrought iron, mild steel, and hard steel.
9. Write down the chemical composition of the following substances, and give a *brief* account of the properties of each:—White lead, red lead, gun-metal, fusible metal, aqua fortis, vitriol, aqua regia, spirits of hartshorn, corrosive sublimate, iron pyrites.
10. What action is exerted by each of the common acids (sulphuric, hydrochloric, and nitric) upon the following metals:—(*a*) iron, (*b*) copper, (*c*) lead, (*d*) silver, (*e*) gold?

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EXPERIMENTAL SCIENCE.

(Heat, Magnetism, and Electricity.)

1. How would you determine the coefficient of expansion of a metal of which a straight rod is given?
   Explain how a compensated pendulum may be constructed from rods of iron and zinc, whose coefficients of expansion are respectively 0·000,011,7 and 0·000,029,5?
2. Explain the terms: *mechanical equivalent of heat*, *specific heat of a gas at constant pressure* and *at constant volume*, and show how the mechanical equivalent of heat may be deduced from a knowledge of the specific heats and the density of any gas.
   How is the mechanical equivalent of heat practically measured?
3. State the causes which influence the rate at which the water of a lake cools and freezes in a severe winter.
   If when the ice is 3 cm. thick, 4×10^5 units of heat are lost per hour from each square metre of surface, what is the temperature of the air in contact with the ice? The coefficient of thermal conductivity of ice is 0·002 (C.G.S.).
4. Give an account of any methods you are acquainted with for producing very low temperatures, pointing out in each case the principle on which the method depends.
5. What are the magnetic elements of any place? State in detail how any one of them may be accurately determined.
6. Give a specimen of iron or steel in the form either of a long thin rod or of an anchor ring, describe the experiments you would make for the purpose of determining its magnetic properties.
7. State the general principles of action of influence (electrostatic induction) machines, and describe and explain the action of one such machine.
8. Explain the terms *dead-beat* and *ballistic* as applied to galvanometers. Describe some form of dead-beat galvanometer and explain why it is dead-beat.
9. A cell of negligible resistance is connected in series with a resistance of 10,000 ohms, and two points in the circuit separated by a resistance of one ohm are joined to the terminals of a galvanometer of 2,000 ohms. If the current through the galvanometer is 0·1 micro-ampère, what is the electro-motive force of the cell?
10. Explain how electric signals may be simultaneously transmitted in opposite directions along a telegraph wire without interfering with each other.

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Geology and Mineralogy.

1. Describe the basalt formation of the North of Ireland or the West of Scotland.
2. Give an account of the distribution of the lowest secondary strata in Ireland or England, and mention any economic substances which they contain.
3. State anything known to you of the occurrence of silver, copper, and lead in the rocks of Ireland or Scotland.
4. Discuss the nature and origin of the chief kinds of valleys met with in Ireland or England.
5. Compare the carboniferous rocks of Ireland and England.
6. Classify the chief kinds of granite found in the British Islands, so as to indicate their mineral and chemical differences.
7. Describe the fossils of the Dingle rocks, or of the carboniferous limestone.
8. Examine the effects of geological structure, and of changes of level in land respectively, in accounting for the configuration of the surface of Ireland or England.
9. Discuss the nature of serpentine, and state the circumstances of its geological occurrence in the United Kingdom.
10. Explain generally the effect of superficial deposits upon the water supply to be obtained from the primary strata.

Part II.

Strength and other Properties of Materials.

[*The Candidate is to attempt not more than* SIX *of the following questions' and, when drawings are necessary for illustration, they are to be* sketches *only, and not finished drawings.*]

1. Write a brief specification for the manufacture of steel plates and bars for bridge building, and specify the tests.
2. Write a brief specification for the cast iron and for the castings required for the columns of a warehouse.
3. Describe the operation of testing a piece of steel to destruction with a tensile strain, stating the condition of the test piece at the various stages.
4. What timber would you specify for the following purposes:—(*a*) piles for a pier on the sea coast, (*b*) railway sleepers, (*c*) roof of a large open shed, (*d*) gates and fencing, (*e*) dock gates, giving your reasons?

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5. What is the comparative strength of either English oak or Baltic redwood when submitted to a tensile and a compressive strain.
6. Write a complete, but brief, specification for the manufacture of a high class Portland cement.
7. Sketch the form of three different test blocks of cement, and state the advantages and disadvantages of each.
8. In making the tests of Portland cement, what defects would you look out for, and what would be the probable cause of these defects?
9. What are the relative values of Portland cement and blue lias lime, and for what purposes or conditions would you specify one in preference to the other?
10. Name three well known sandstones, two oolites, and two granites, and state the purpose for which each is best adapted.
11. Name four different kinds of bricks and the purposes for which each is best adapted. State the tests for ascertaining the qualities of a brick.
12. What kind of concrete, and in what proportion, would you specify for the following:—(*a*) foundation of large building on clay, (*b*) on sand, (*c*) dock walls, (*d*) arches for warehouse floors, (*e*) foundation for wood roadway paving.

Calculation of Stresses and Strains.

[*The Candidate is to attempt not more than* SIX *of the following questions, and, when drawings are necessary for illustration, they are to be* sketches *only, and not finished drawings.*]

1. Draw a diagram giving the bending moments and shearing stresses of a girder 20 feet long supported at each end, loaded uniformly with 2 tons per foot run and with a central load of 5 tons.
2. Having ascertained the shearing stresses, how do you determine the thickness of the web plates and the position of the stiffeners?
3. Sketch the joint of two bars $12'' \times 1''$ to be submitted to a tensile strain; the rivets to be 1″ diameter, and a minimum number to be used; the nett strength of the bars, the cover plates and the rivets at the joint to be practically the same. Assume the unit strength of the material to be the same for a tensile and a shearing strain.
4. Draw the stress diagram of a parallel braced girder 100 feet span, 10 feet deep, and having 10 bays of vertical struts

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and inclined ties, single triangulation, and having a load of 10 tons applied at each bottom joint.

5. Draw the stress diagram for the above girder (Question 4) showing the effect of applying a load of 20 tons to the third bottom joint from the end.
6. Draw the diagram of the forces which keep a retaining wall in equilibrium, assuming weights and dimensions.
7. State Gordon's formula for columns with flat ends, and work out an example.
8. In designing a brick pier in the centre of a building of, say, six floors, how would you ascertain the dimensions of the pier at the various floor levels, assuming the floor girders to be firmly fixed at the pier and at the walls?
9. How do you determine the strength of a thin cylindrical shel when submitted to internal pressure—such as the shell of a steam boiler?
10. How do you ascertain the strength of the corrugated plates commonly used for bridge flooring? Give an example, assuming dimensions and loads.
11. Determine the tension in a cable of a suspension bridge at the pier, at the lowest point, and in the backstays, when the uniformly distributed load is W, the span S, and the dip *d*, the backstays being at an angle of 45°. What is the pressure on the piers, the cable being free to move?
12. Draw the diagram of the pressures on a dock gate, with a depth of water of 30 feet on the dock side, and a depth of 5 feet on the lock pit side.

Railway Engineering.

[*Do not attempt more than* SEVEN *questions.*]

1. Draw a plan showing the sidings, platforms, &c., you would provide for a station on a single line of railway to accommodate a town of about 5,000 inhabitants.
2. Sketch the arrangements of signals, point rods, &c., for such a station. Which of the points shown should be provided with locking apparatus?
3. Make a drawing for a locomotive ash-pit. Scale, $\frac{1}{4}$ inch to 1 foot.
4. Draw a cross-section through the centre of a plate girder bridge, 60 feet span, road on top of girders. Show rails, sleepers, &c. Scale, $\frac{1}{2}$ inch to 1 foot.
5. Design a masonry bridge to carry a public road over a double line of railway (Irish gauge), the railway being in 6 feet of cutting. Scale, $\frac{1}{8}$ inch to 1 foot.

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6. Draw, full size, the cross-section of a bull-headed rail, 80 lbs. per yard.
7. Make a sketch plan for the junction of a branch line with a main line of railway (both lines being double) *not* at a station; the main line being in 25 feet of embankment. Show arrangement of signals.
8. Describe in detail the process of plate-laying.

Canal Engineering.

[*Do not attempt more than* SEVEN *questions.*]

1. What engineering considerations should guide you in laying out a canal for navigation purposes?
2. Describe the works necessary for taking off water from a river to supply an irrigation canal.
3. Describe any kind of movable weir with which you are acquainted.
4. Write a specification for the earthworks for a canal, in cutting and in embankment.
5. Sketch a canal lock, lift 8 feet, to take barges of about 75 tons carrying capacity.
6. Sketch the cross-section you would adopt for a reservoir dam about 70 feet high, and write a specification for the construction of such a dam.
7. Describe the method you would adopt for securing the foundations of a weir across a wide river; borings showing silt to a depth of over 100 feet.
8. Write out a specification for Portland cement to be used in hydraulic works.

Marine Engineering. (1.)

[*Answer not more than* SEVEN *questions. Wherever you can, quote personal experience in support of your answers.*]

1. How is cement tested for fineness, strength, and hydraulic properties?
2. Specify the fineness, weight, strength, and hydraulic properties of good Portland cement.
3. Does the use of sea water in mixing cement give as good a result as fresh water? And which is preferable, sea or river sand?

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4. Specify the proportions of broken stone, sand, and Portland cement you would use for concrete *in situ* under water, and for concrete blocks.
5. In making large concrete blocks is it economical or advisable to put blocks of stone into concrete, and, if so, what precautions should be taken in their use?
6. Is there any advantage in bulking cement instead of using it direct from barrels when dealing with large quantities?
7. When requiring 150 cubic yards of concrete of 6 to 1, state the quantity of each material you would order for the purpose; stone, sand, and cement.
8. Give a section, with dimensions, of a solid quay wall for a depth of 18 feet of water with a 10 ft. rise of tide on a moderately soft clay bottom.
9. State what different methods have been adopted for obtaining foundations for a solid quay wall in soft ground.
10. Draw a section of a timber quay on a clay bottom in 15 feet of water and a 6 foot rise of tide, giving the length and dimensions of piles and timbers throughout. Assume the ground at back to be clay, and level with the top of the quay, and provide for maintaining a proper slope of $1\frac{1}{2}$ to 1; the toe of the slope not to project beyond the face of the quay.

Marine Engineering. (2.)

[*Answer not more than* SEVEN *questions. Wherever you can, quote personal experience in support of your answers.*]

1. What are the various means in use for fixing piles into clay, sand, or gravel?
2. Describe the various kinds of iron piles in use, giving sections and dimensions of each.
3. State the main principles on which breakwaters are constructed, and name examples illustrating their use.
4. State the various ways in which concrete is used for the construction of breakwaters.
5. How is the foundation obtained for a solid breakwater of concrete blocks, and how is it prepared for receiving the bottom blocks? If a breakwater has to be constructed from low water of concrete in mass, how would you construct the portion up to low water?
6. Give a list, and describe the use, of the most important machines required for constructing a breakwater composed mainly of blocks of 30 tons weight.

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7. In the construction of a breakwater what means have been employed to bind concrete blocks under water? Give examp es of failures from not having done so.
8. Give the various means employed for removing from under water sand, clay, and rock.
9. State the various ways in which mud, sand, and silt are disposed of when dredged.
10. What are the essential data required before a graving dock can be designed?

Hydraulic Engineering. (1.)

(Water Supply.)

[*Only* SEVEN *questions to be answered. Wherever you can, quote personal experience in support of your answers.*]

1. Describe a rain-gauge, and explain how you would dispose of a number to arrive at a close approximation to the rainfall of a watershed.
2. What considerations govern the proportion of the rainfall on a watershed that may be made available for the water supply of a community? What is the usual loss from evaporation and absorption in this country?
3. What formula would you use to calculate the flow in a riveted steel pipe? Calculate the discharge of such a pipe 3 feet diameter with a hydraulic gradient of 5 feet per mile.
4. Draw a self-acting stop-valve for the above water main to a scale of 1 inch to a foot. What rate of closing should be the maximum allowable?
5. Describe any one system, with sketches, of putting down a bore-hole.
6. Design a service reservoir, situated near a town, half its depth in the solid ground, to contain 20 million gallons of water, to a scale of 50 feet to an inch.
7. Take out the quantities and estimate the cost of the reservoir in the foregoing question.
8. Calculate what indicated horse-power would be required for lifting 2 million gallons of water per day from a river into a service reservoir 100 feet above the intake, and five miles away, through a pipe two feet in diameter.
9. Write down a list of regulations, giving reasons for same, for working a system of seven filter-beds for filtering a town supply.
10. In a town where considerable waste of water is known to exist, owing to defective fittings, give details of how you would proceed to remedy the evil.

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HYDRAULIC ENGINEERING. (2.)

(Sewage and Irrigation.)

[*Only* SEVEN *questions to be answered. Wherever you can, quote personal experience in support of your answers.*]

1. What size would you make an intercepting sewer that has to convey the sewage of a town of 20,000 inhabitants, so as to be self-cleansing?
2. How would you treat the above sewage chemically, supposing the town to have few manufactures?
3. Sketch a system of treating the same sewage by the bacteriological process.
4. Draw to scale an automatic flush-tank, to flush a sewer 2 feet diameter.
5. What is the difference in the arrangements for sewage disposal by broad irrigation and intermittent filtration through land, and what is the action in each case?
6. Sketch an efficient means of arranging the drainage from a house and trapping it from the main sewer.
7. What are the objects of water-meadow irrigation as practised in this and other countries? What sources of water supply are most suitable for it?
8. Sketch an undershot water-wheel, 20 feet high, for lifting water for irrigation purposes, supply level 5 feet below axis of wheel; and describe any other method you know of for lifting water for this purpose, other than steam power.
9. Describe any form of module you are acquainted with, used in gauging water for irrigation purposes.
10. Give a formula, and state how it is derived, for calculating the flow of water in irrigation canals, and state what coefficients you would use (1) for pitched slopes and bottom, (2) for sand.

COUNTY WORKS. (1.)

(Architecture.)

[*Not more than* FIVE *questions to be answered.*]

1. Illustrate, by sketches, three methods of laying floor boards with secret joints, and state the advantages, or otherwise, of each method.
2. Draw to a scale of $\frac{1}{8}$-inch to the foot a plan and front elevation of a cottage suitable for a coast-guard officer. Specify, briefly, materials to be used in its construction.

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3. Draw, to a scale of quarter of an inch to a foot, the timbering necessary to secure the front wall of a building 40 feet in height inclining towards the street. Figure the dimensions of the timbers used, and indicate the direction of the strains by arrows.
4. Describe the architecture of the different periods of Gothic, and illustrate each style by a freehand sketch.
5. Write a specification for removing the roof of a courthouse, and retimbering and slating, including painting the whole of the wood and iron work usually painted, of the interior and exterior of the building.
6. To what circumstances would you direct special attention in selecting a site for a residence?
7. Describe a suitable method of ventilating and warming a public building. Illustrate your answer by sketches.
8. Draw the capital of a Corinthian, a Doric, and an Ionic column. Name the different members, and give their heights in parts of a module.

County Works. (2).

(Roads.)

[*Not more than* FIVE *questions to be answered. Wherever you can, quote personal experience in support of your answers.*]

1. Name the principal kinds of stone used for macadamising roads in Ireland. State the merits or demerits of each kind of material.
2. Write a short specification for making a new line of road, dealing with the subject under the following heads, viz.: "Laying out," "Forming," "Slopes," "Drainage," "Fences," "Gripes," "Retaining and parapet walls," "Paving and metalling," "Depôts for broken stones," "Conditions," &c.
3. State what you know of machine broken macadam, and compare it with similar material broken by hand.
4. What circumstances conduce to bad road surfaces? State the methods you would adopt to remedy the defects due to such circumstances.
5. Draw a plan and transverse section of a short length of main road leading from a town to a railway station. Show the formation of the road, and state the method of construction. Provide a footpath on one side.

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6. What is the maximum gradient you would allow in a new road connecting two towns, and the maximum working gradient admissible in a side road to be used for local traffic only?
7. What would be the increase of tractive force per ton hauled on the maximum gradients you would allow, in the cases named in the foregoing question, over that required on level roads under similar circumstances?
8. State in general terms the system you would recommend for the repairs and maintenance of county roads.

County Works. (3.)

(Drainage and River Works.)

[*Only* FIVE *questions to be answered, and only* THREE *out of the first* FIVE. *Wherever you can, quote personal experience in support of your answers.*]

1. Why are the arches of bridges of brickwork generally constructed in concentric rings instead of with radial joints continuous throughout the depth?
2. Draw to a scale of $\frac{1}{2}$-inch to the foot a transverse section and part elevation of a rubble wall for protecting a river bank, total height of wall above river bed 18 feet, depth below bed to solid foundation 7 ft. 6 inches.
3. Write a short specification for the construction of the wall mentioned in the foregoing question, and prepare an estimate of the cost of the work, the length of the wall being 100 yards.
4. Under what circumstances do coffer-dams become necessary in river work? Draw to a scale of $\frac{1}{4}$-inch to a foot a section through a coffer-dam, and describe the method of making it, and the materials to be used in its construction.
5. Draw to a scale of $\frac{1}{8}$-inch to the foot a plan and elevation, with longitudinal and transverse sections, of a bridge (with its approaches) to carry a road over a river, the latter being 40 yards wide, the banks 6 feet high, the land on one side level for a distance of 60 yards from the bank, and liable to be occasionally submerged to a depth of 3 feet.
6. Write a short specification for draining and reclaiming 40 acres of wet land, the subsoil composed of clay, marl, and sand. Prepare an estimate of the approximate cost of the work.
7. What drainage would be necessary for a road crossing over marshy land or bog? Illustrate your answer by sketches.

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8. Draw to a scale of $\frac{1}{8}$-inch to the foot, a plan, elevation, and section of a river tilting weir to impound and pass when closed a normal flow of 20 million cubic feet per 24 hours, and to be capable of discharging when open 200 million cubic feet per 24 hours.
9. Describe a suitable appliance for preventing the back flow of water from a river upon adjoining low-lying lands, in times of flood. Illustrate your answer by a sketch.

EXAMINATION FOR ASSISTANT TO COUNTY SURVEYOR IN IRELAND.

MENSURATION.

(Time allowed—Two hours.)

[*Not more than ten questions to be answered.*]

1. (*a.*) How many statute perches are equal to 320 Irish perches lineal ?
   (*b.*) How many statute acres are equal to 121 Irish acres ?
2. The lengths of the sides of a triangular field are 400 feet, 300 feet, and 500 feet. What is the area of the field in statute perches ?
3. A water main of 12 inches internal diameter is flowing full bore at the rate of 10 lineal feet per second : calculate—
   (*a.*) Number of cubic feet delivered per minute.
   (*b.*) Number of gallons delivered in 24 hours.
4. A rectangular field contains 6 acres 3 roods 10 perches, statute measure. Its length is 250 yards. What is its width ?
5. A circular arc has a height of 2 feet and a chord of 40 foot long—
   (*a.*) What is the diameter of the circle ?
   (*b.*) What is the length of the side of a square which could be exactly fitted inside this circle ?
6. A room is 24 feet 8 inches long, 15 feet 4 inches wide, and 11 feet high—
   (*a.*) How many yards of paper 21 inches wide would be required for papering it, assuming that the area of the doors and windows equals the necessary waste ?
   (*b.*) What would be the number of lineal yards of carpet 27 inches wide required to cover the floor of this room ?

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7. If a rainfall of 16 inches can be collected and distributed throughout a year from a catchment area of one square mile, how many people can be supplied at the rate of 25 gallons per head per diem ?
8. What must be the dimensions of a rectangular cistern, with a square base and depth equal to two-thirds of a side of the base, to contain $666\frac{2}{3}$ cubic feet of water ?
9. How many cubic yards are in a heap 81 yards long, the cross-section of which is $6\frac{1}{2}$ feet wide at bottom, 5 feet wide at top, and 14 inches deep ?
10. What fraction of the surface of a road $16\frac{1}{2}$ feet wide could be patched with broken stone supplied to the extent of 40 cubic yards per mile, assuming that one cubic yard is so spread as to cover one square perch statute ?
11. A cutting for a new road 18 feet wide is 540 feet long, and the depth at the two ends are 20 and 30 feet. The ground is level and plane across the top of the cutting. The side slopes are to be made $1\frac{1}{2}$ to 1. Calculate—
(*a.*) Contents of cutting in cubic yards.
12. (*b.*) What is the area of the side slopes of cutting in square yards, and the acreage in statute measure of the land required, allowing 6 feet on each side outside the top of the slopes for fencing ?

English Composition.

(Time allowed—$1\frac{1}{2}$ hours.)

Write shortly on *one* of the following subjects :—
1. Engineering Triumphs.
2. The duties of an Assistant County Surveyor.

Construction and Maintenance of Roads.

(Time allowed—Two hours.)

[*Not more than ten questions to be answered.*]

.1 Explain the difference in the methods of forming roads adopted by Macadam and Telford.
2. (*a.*) Draw to the scale of $\frac{1}{4}$ inch to one foot a cross-section showing the construction of an important county road, carriage-way 18 feet, footpath on one side 6 feet wide,

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with granite curbing. Show at one side usual mound fence. Give the dimensions of every part of the work and describe the materials.

(*b.*) Write a short specification for the construction of this road.

3. Give an estimate in detail for the construction of a mile in length of the road described in question 2.
4. (*a.*) What kind of stones are used, to your knowledge, for forming and repairing macadam roads in Ireland, and what are the qualities of each ?

   (*b.*) How is the size of broken stone for road repairs usually specified and tested ?
5. Write a brief specification for taking up an old gravel footpath and making a concrete path with granite curbing instead.
6. State what you know of the advantages of steam-rolling for road construction or repairs ; how steam-rolling should be done ; and what it usually costs to consolidate a cubic yard of stones in coating three inches thick.
7. What are the advantages and disadvantages of breaking stones for roads (*a*) by hand, (*b*) by machinery ?
8. State the most important points to be attended to in repairing an important road with broken stones without the use of a steam-roller.
9. What are the principal matters to be attended to in maintaining a road in good order ? State in detail the work which should be done in spring, autumn, and winter.
10. State how ruts in roads should be prevented, and how, if through neglect they occur, they should be repaired.
11. What are the advantages of cross-sweeping a road ? and what are the special advantages gained by the employment of constant labourers on important roads ?
12. Why should roads not be made perfectly level longitudinally, and what are the disadvantages of roads with too great cross curvature ?

Chain Surveying and Levelling.

(Time allowed—Two hours.)

[*Not more than eight questions to be answered.*]

1. Describe in detail Gunter's chain, and state the length of one link in inches. What are the advantages and disadvantages of Gunter's chain compared with a chain 100 feet long ?

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2. (*a.*) Describe the method of ranging and measuring a straight line on hilly ground.
   (*b.*) Explain one method of extending the line over a river wider than the length of the chain.
3. Explain by a sketch and notes the method of putting in levels by means of "Boning Rods" between two points whose level is known.
4. Explain how you would proceed to join two lines at an angle by a circular curve, showing how you would make your calculations, and how you would perform the laying out on the ground.
5. Draw three irregularly-shaped adjacent fields, and show by dotted lines the field lines and offsets by means of which you would make a survey of the field.
6. Describe—
   (*a.*) The principal permanent adjustments of the Dumpy level.
   (*b.*) The temporary adjustments necessary when it is set up.
7. Rule a page of the level book you are accustomed to. Write proper headings, and enter readings, showing about a dozen readings, with three changes of the position of the level, and reduce the levels.
8 (*a.*) What are the scales of the Ordnance Maps in general use in this country?
   (*b.*) How many feet are represented by a length of one inch on a map on the scale of 10.56 feet to one mile?
9. (*a.*) Explain the meaning of contours on a map.
   (*b.*) Explain the meaning of Ordnance Datum.
10. The levels of two points a mile apart on a regular incline are 172.36 O.D. and 34.78 O.D. Express the gradient between them in two ordinary ways, and give the level of an intermediate point one-quarter of a mile from the lower end.

Arithmetic Paper.

(Time allowed—$1\frac{1}{2}$ hours.)

Note.—*Candidates are not required to answer more than six questions altogether, of which not more than four must be from Section A, and not more than two from Section B.*

Section A.

1. Divide the sum of $\frac{5}{9}$ and $\frac{8}{6}$ by $7\frac{3}{4}$, and subtract the quotient from $3\frac{1}{4}$ of $6\frac{12}{13}$.
2. Find the sum, difference, product, and two quotients of 30.33 and .0337, and find the sum of all the results.

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3. Reduce 37,543,473 square inches to acres.
4. Find the value of 7 gall. 1 qt. 1⅜ pts. at 17s. 4d. a gallon.
5. Divide 53 miles 3 fur. 23 poles 4 yds. 2 ft. by 35.
6. Find the amount of the following bill :—

2,743	articles	at 10¼d. each -	£
137	,,	at £1 10s. 11½d. each	£
34,986	,,	at 2s. 3d. each -	£
176	,,	at £2 3s. 7¼d. each	£
		£	

Section B.

7. The stuff out of a lead mine contains at first 15.9 per cent. of lead. After washing, by which process the amount of lead ore is not diminished, the stuff contains 87.45 per cent. of lead. How much rock (in tons and fractions of a ton) was washed away out of 216 tons 5 cwts. of the original stuff ?
8. On a piece of work three men and five boys are employed, who do half of it in six days. After this one more man and one more boy are put on, and one-third more is done in three days. How many more men must be put on that the whole may be completed in one day more ?
9. If 15s. be paid for a piece of work which A and B could do in 8 hours, or B and C in 9 hours, or A and C in 10 hours ; find A's wages for a working day of 8 hours.
10. A contractor employs a fixed number of men to complete a work. He may employ either of two kinds of workmen : the first at 26s. 6d. a week each, the second at 18s. 6d. a week each ; the work of one of the former being to that of one of the latter as five to four. If he finishes it as quickly as possible, he spends £270 more than he would have done if he had finished it as cheaply as possible, but takes four weeks less time. Find the fixed number of men employed.

Building Construction.

(Time allowed—Two hours.)

[*Not more than eight questions to be answered.*]

1. Write briefly—
   (*a.*) Specification for lime mortar for building :
   (*b.*) Specification for Portland cement mortar for use in superior masonry ;

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(*c.*) Specification for Portland cement concrete for use in the foundations of a bridge.

2. Write a short specification for laying a 12-inch pipe sewer or drain, stating quality of pipes, method of jointing, precautions to be observed to secure good work, and the method of filling the trenches.

3. (*a.*) What is the distinctive difference between Ashlar and Rubble masonry?

(*b.*) Draw sketch elevations of "*Random rubble in courses,*" "*Squared rubble built in courses,*" and "*Regular squared coursed rubble.*"

4. (*a*). Draw a neat hand sketch cross-section of an arch culvert under a road, span of arch 9 feet, rise of arch 3 feet, height from foundation to springing 7 feet. Give all the principal dimensions.

(*b.*) State at *what* stage in the building you would remove the centres.

5. (*a.*) Sketch a suitable section, with dimensions clearly marked, of a retaining wall and parapet at the side of a road, depth from road level to foundation 15 feet.

(*b.*) Write a brief specification for the work, assuming it to be on a country road.

6. Explain the following terms used in connection with bridges:—Abutment, Pier, Springing, Springer, Sheeting, Haunching, Spandril, Quoins.

7. (*a.*) Define in words and show by a sketch what is meant by "Lap" in slating.

(*b.*) Describe in what way slates are supported, and the methods of nailing them.

8. Sketch in elevation one or two courses of Brickwork (*a*) in English bond, (*b*) in Flemish bond, and explain what a "closer" is.

9. Give sketches showing inside and outside of—

(*a.*) An ordinary ledged door;

(*b.*) A framed and braced door;

(*c.*) A panelled outside door for an exposed position.

10. Give hand sketch showing the construction of the woodwork of an ordinary window 6 feet by 3 feet, with both sashes hung, marking sizes of principal parts.

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[*2nd December*, 1903.]

Annual General Meeting.

Mr. John H. Ryan, President, in the Chair.

The Officers and Council for 1904 were balloted for and duly elected (see List of Members).

The following Candidates were balloted for and duly elected :—

Dudley Perceval Griffith, William J. Perrin Wakeman, Edward S. O'Brien and Henry Wray Clarke as Members; and Jas. Berkeley Wise, Arthur White Bretland and Thomas Tomlinson as Associate Members.

Some Simple Forms of Geodetical Instruments for Rapid Survey Work.

By Sir Howard Grubb, F.R.S., Honorary Member.

Much of the detail surveying work of the Civil Engineer is necessarily done with instruments that are much more elaborate, cumbersome and costly than are at all necessary for the purpose.

Delicate instruments, such as the Theodolite, have often to be put into the hands of unskilled assistants to do work of detail which it would not pay to employ highly skilled labour upon, simply because there is no other instrument for the purpose, and as a consequence, when their principals require the same theodolite for purposes in which great accuracy is required, and for which it is really suited,

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the instrument is often found out of adjustment, and a loss of accuracy occurs in some very essential part of the survey.

Various attempts have been made from time to time to fill up the gap which exists between such very rough hand instruments as are available and the elaborate standard instruments, but there are not many such that can be said to have found favour with the surveyors.

The principles of the gun sight, which I patented a few years since, appeared to me to offer facilities which did not before exist for the production of a set of instruments which would fulfil the necessary conditions, and consequently I devised a number of these suitable for various purposes, and for varying conditions, which instruments I now beg leave to bring under the notice of the Institution of Civil Engineers in Ireland.

General Principles.—When a comparatively close object is viewed through a magnifying lens placed at its own focal distance from that object, the pencils of light which enter the eye are composed of parallel rays, consequently the effect is the same as if the object under view was a large one at a great distance instead of, what it really is, a small one at a short distance. In other words, a virtual image of the object will be formed at a great distance in front of the observer.

The lens used for parallelizing the rays is called the "collimating" lens.

If, now, some device be adopted by which these parallelized rays enter the eye simultaneously with those from a distant object, it is evident that we shall see this virtual image of the near object projected upon and apparently in the same plane as the distant object.

The more usual arrangement for utilizing this double set of rays (one from the near object and the other from the distant object) is, to so plan the apparatus that half of the

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pupil of the eye is utilized for the rays from the near object, and the other part of the pupil for rays from the distant object, but as this necessitates an absolute fixity of position of the eye of the observer, a condition difficult of fulfilment in the case of such appliances as gun-sights and hand-surveying instruments, I effect the desired result without the above disadvantages by interposing in the path of the rays from one of the objects a semi-transparent and semi-reflective film, which allows the rays from one object to pass through it, while it reflects the rays from the second object into the pupil of the eye.

In the case of such instruments as mining dials, where artificial light must be used, and where there is no difficulty in obtaining a sufficiently brilliant illumination of the near object, it suffices to use a piece of plain parallel glass for this purpose, which allows the rays from the distant object to pass through, while it reflects the parallelized rays from the near object with sufficient brilliancy.

In the case of most of the instruments under consideration, however, the source of light for illuminating the near object is generally the sky, which is often not much more brilliant than the distant object, so it is necessary to use some medium which will have a greater reflective power than the naked surface of the glass.

Various substances have been tried deposited in thin layers on glass, but nothing has been found to equal in effectiveness an amorphous film of PbS. deposited by a chemical process, invented and patented by Dr. J. Emerson Reynolds, F.R.S. and my son, Mr. G. Rudolf Grubb, M.A.I. This film can be deposited of any required thickness so as to give the desired proportion between the reflected and transmitted rays. Its absorption is very low, and nearly all the rays are either reflected or transmitted.

By a combination of these two devices—viz., the semi-

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reflective, semi-transparent film, and the collimating arrangement above described, it is possible to project on a distant object any mark, device, or scale, which will then be seen simultaneously with, and superposed upon, that object, and by which that object can be correctly sighted, or by which its bearing as regards other objects or any fiducial point can be obtained.

The original conception and simplest construction of one of these sights is shown in Fig. 1, where it will be seen that the

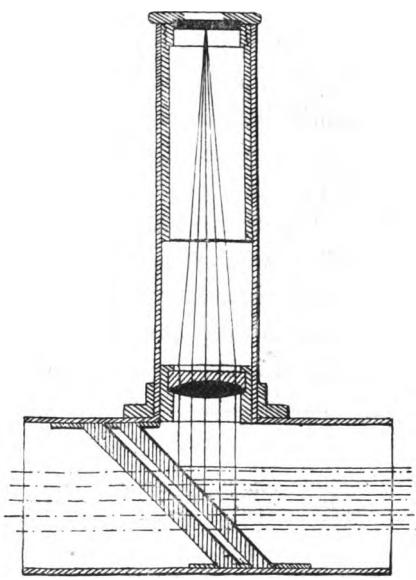

Fig. I.

rays from the distant object enter the eye without any deviation from their ordinary course, while the rays from the near object, parallelized by the collimating lens, enter the eye under exactly the same conditions, so that the effect is that of a large cross imprinted or superposed upon the distant object.

That this virtual image of the + is really formed on the

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same plane as that of the distant object is shown very clearly by inspection of the Figs. 2 and 3, which are facsimiles of photographs taken of and through one of the sights.

In the first case, Fig. 2, with the camera placed behind the sight and focussed on the sight itself, the body of the instru-

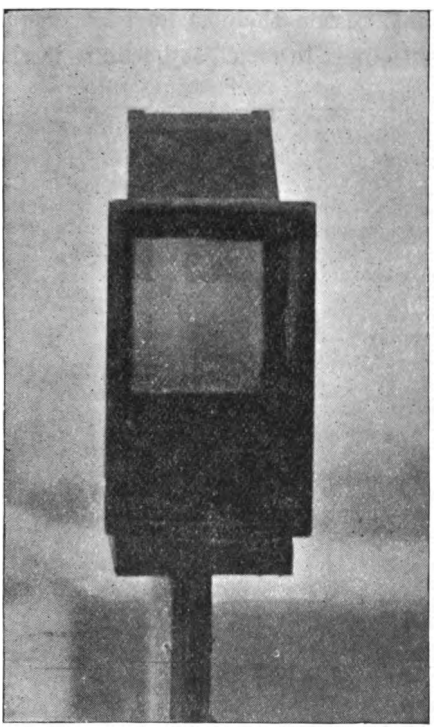

Fig. 2.

ment can be seen quite sharp, but the distant view and image of the + are so much out of focus as to be invisible.

In the second photograph, Fig. 3, the camera was racked in till the distant view was distinct, and in this the + is seen quite sharp and distinct, showing that it is formed on the plane of the object.

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The peculiar advantages of such a sight can readily be appreciated.

As the + or mark is projected or imprinted on the object to be sighted no parallax is possible, which shows that the eye of the observer need not be kept rigidly to one position; in fact no backsight is necessary.

For the same reason there is no effort required to keep both sight and object in focus, as both are in the same plane

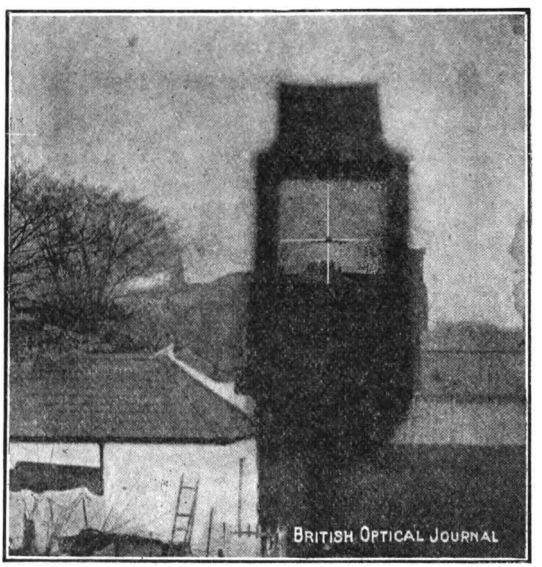

Fig. 3.

and at the same distance from the observer, and as a consequence of this, any form of telescope or field glass can be used to help the observer, which when focussed accurately for the distant object will show the + or device perfectly sharp and well defined.

Such are the general principles on which the patent gun-is constructed: The form varies to suit different

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conditions. The most usual form is that designed by Mr. G. Rudolf Grubb, and shown in Fig. 4.

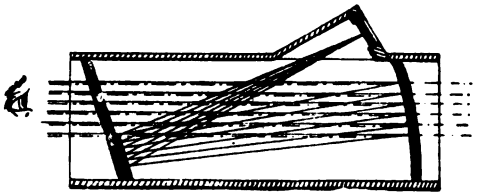

Fig. 4.

It can be readily understood that the same principles can be utilised in various geodetical instruments. The prismatic compass, clinometer, graphometer, hand levels, and many other instruments have been constructed on the same lines as in the gun-sights.*

In these surveying instruments the divisions of the compass card (as in the prismatic compass), or the divisions on the arc (as in the clinometer), or scale of equal parts (as in the graphometer), are projected on to the object itself, and the readings are obtained with an ease and quickness hitherto unattainable. It may be mentioned that in all instruments in which divisions of a circle are used, the optical parts are so proportioned that the divisions as seen projected on the object actually represent their true angular values.

It is not necessary, therefore, to make (as in the old form of instruments) a coincidence between a fiducial line and object and then between fiducial line and division on scale, but each object has projected on it the particular division which represents its true bearing, no matter whether it be in the centre of the field or to either side; and consequently an alteration in the position of the instrument, due to the unsteadiness of the hand, or other cause, makes no error in the reading so long as the object can be seen anywhere in the field.

* For description of these see Appendix to paper.

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In most of these devices telescopic power can be utilised, and if a binocular telescope is used it will be found advantageous to look through the instrument with one element of the binocular and alongside the instrument with the other element; or, if no telescopic power be used, to keep both eyes open and observe the object with one eye looking through the instrument and the other directly at the object.

I do not for a moment suggest that any of these instruments should replace standard surveying instruments, but I hope they may be found useful in filling up the gap between the elaborate instruments and the existing forms which are not very reliable.

THE PRESIDENT (Mr. J. H. Ryan) said he was sure they would all join with him in according a hearty vote of thanks to the author for the extremely interesting paper which he had given them, and for the very elaborate instruments with which he had exemplified the paper; also for the trouble he had taken in bringing the photos and slides, which added very much to the interest of the paper.

MR. GLOVER seconded the vote of thanks, and said the first question that occurred to him was whether these instruments were on sale or not.

In his early days—he might say up to the present time—when he went to inspect he had to carry instruments weighing about half a ton with him, and this was very expensive. If he had some of the instruments described by the author they would be very useful, and also to any of those who had to make lengthy surveys. There was no doubt for practical men, especially in Ireland, where they had to deal with acres, not square miles, these instruments were what they wanted.

He had a few instruments in the shape of a box sextant, vertical angles, &c.; but sometimes he was compelled to fall back on the straight edge and the carpenters' level.

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If the author could help them to get some accurate instrument instead of having to carry about theodolites, &c., he would save them a great deal of expense.

SIR HOWARD GRUBB said some of the instruments were made by Hicks, of Hatton Garden, and some by Davis & Sons, Derby.

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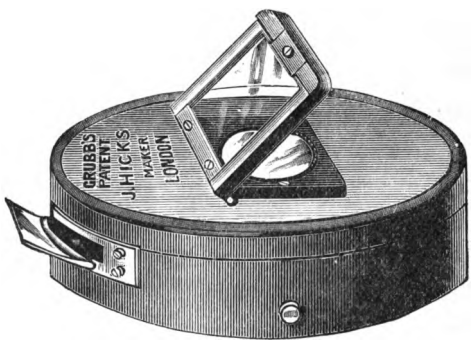
APPENDIX TO MR. GRUBB'S PAPER.

THE PRISMATIC COMPASS.

The above possesses the same advantages over the ordinary form as are mentioned in the case of the Clinometer. (*See* II. in Appendix.)

To Use the Prismatic Compass.

(1.) Raise the square frame carrying the semi-transparent mirror to its highest position—viz., 45°.
(2.) Open the shutter in front.
(3). Hold the instrument in the usual position—*i.e.*, horizontal, looking at object through the semi-transparent mirror.
(4.) Set free the compass card by the button at side.



The object will now be seen with a horizontal scale projected upon it. Should the divisions be not distinctly seen when superposed on the object the instrument is not correctly pointed, but a slight twist in a horizontal plane will make this right.

It will be observed that the bearing of any object is the same no matter what angle the box is held at, so long as the scale is within the field.

When the card is steady, the division superposed on any object represents the true bearing of that object; or observations can be taken of the superposed division at the extreme end of the card, right and left, and the mean of these two observations is the true bearing.

If the illumination of the scale be not satisfactory, it can often be improved by half closing the shutter of the window in front and reflecting sky light into it.

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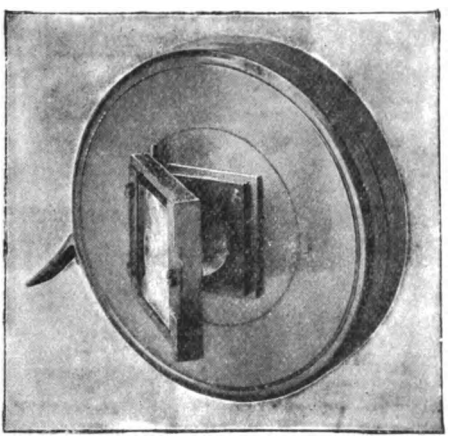
CLINOMETER.

The general form of the Clinometer is very similar to that commonly in use, with the exception that the "Grubb" Clinometer has a hinged frame near the centre of the box which can be raised to an angle of about 45°, and carries a piece of semi-transparent glass as described above.

In using the instrument there is no necessity to look through a pair of small holes as in the ordinary form. The observer simply looks through the inclined semi-transparent mirror, holding the Clinometer in the usual position, and a scale of half degrees will then be seen projected upon the object.

There is no fiducial line. The elevation of any object is read off by noting the particular division of the scale which is superposed upon that object.



The advantages over the ordinary clinometer are :—

(1.) It is not necessary to make a double coincidence.
(2.) The scale is seen sharply projected upon the object.
(3.) It is not so necessary to hold the instrument perfectly steady as in the ordinary clinometer.
(4.) The field of view is not confined.

To Use the Clinometer.

(1.) Raise the square frame carrying the semi-transparent mirror to its highest position—viz., 45°.
(2.) Open shutter in front.
(3.) Hold instrument in usual position—*i.e.*, in the left hand, and look at object through the semi-transparent glass.

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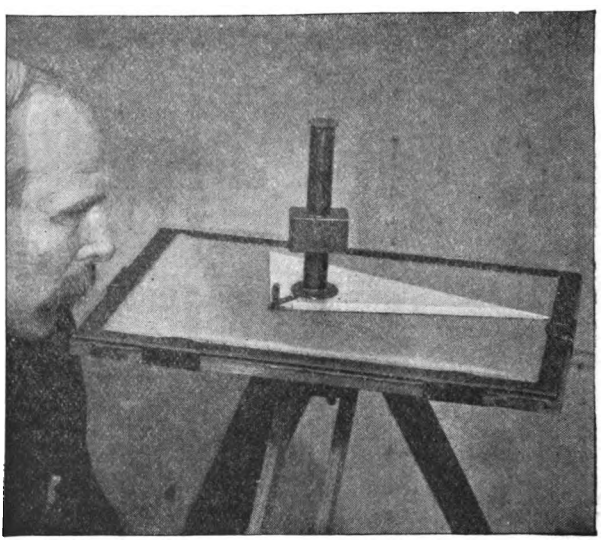
(4.) Set the pendulum swinging by drawing to the right the small pin found at side.

The object will now be seen with a vertical scale projected upon it. Should the divisions be not seen distinctly when superposed on object the box is not correctly held, but a slight twist in a vertical plane will make this right.

It will be observed that the reading of any object is the same no matter what angle the box is held at.

When the pendulum is at rest the division superposed on any object represents the angular height of that object. If the background of object be very dark and that the scale be not brilliant enough, a better illumination can generally be obtained by half closing the shutter in front and reflecting the sky light into the window.



THE GRAPHOMETER.

This instrument is constructed in such a manner that it can be used either as a simple Plane Table for plotting angles, the necessary distances being obtained by direct measurement, or it can be used as a Telemeter combined with a Plane Table, no direct measurements in that case being necessary.

To Use Graphometer as a Plane Table.

(A.) Set up the instrument on a levelled Plane Table, and use exactly as the ordinary sights usually supplied with same.

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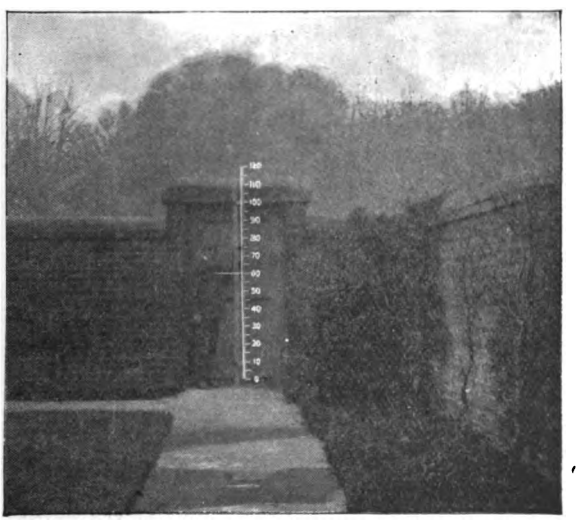
The result will be much less liable to error, and the instrument is much more easily worked by inexperienced persons.

(B.) To use Graphometer as a combined Telemeter and Plane Table :—

(1.) Select a convenient base, and let a 10-foot range rod be held at one end.

(2.) Set up Plane Table at the other end of this base and plant upon it the triangular base of the Graphometer, the corner supplied with the needle being placed on the paper at that spot which is to correspond with that end of the base, and insert the needle at this point for a centre.



THE GRAPHOMETER.

(3.) Turn round the instrument on the needle as a centre, till the 10-foot staff representing the other end of the base is seen to correspond with the vertical fiducial line in the field of the Graphometer. Draw a line now along the graduated edge of triangular base, and this will represent the *direction* of the base.

(4.) Count the number of divisions occupied by the 10-foot ranging rod on scale in Graphometer, and place a mark opposite corresponding figure on the graduated edge of the triangular base. This will truly represent the position of that object on the survey. Repeat for all other points of the survey.

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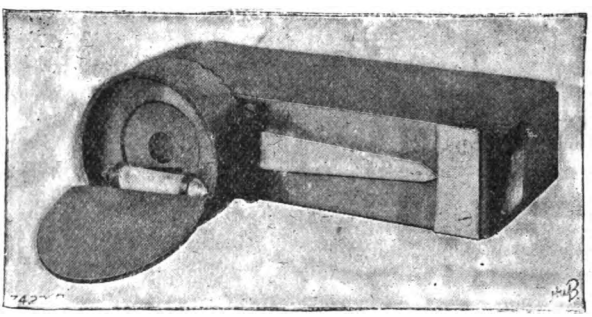
The accuracy obtainable with this class of instrument diminishes rapidly as the distances of the objects increase. The operator therefore must exercise his judgment as to how far it is desirable to use the instrument as a Telemeter.

If the distances be large and the accuracy required be more than can be expected from such a method, it is desirable to plot the larger triangles by the first method, in which the base is obtained by direct measurement, and then fill in details by the second method. On the other hand, very rapid work, combined with an accuracy generally sufficient for military or prospecting surveys, can be obtained by employing the second method only.



THE LEVEL.

The general form of the Level is very similar to that of the "Abney" level.

In using the "Grubb" instrument a + which forms the fiducial mark is seen projected upon the object which is observed through the rectangular tube. A portion of the spirit level is also seen distinctly visible.

To Use the Level.

(1.) Open the polished flap in front of Level bubble.

(2.) See that the head and the arm at side are set to O if it be desired to range a level line.

(3.) Look at object through tube and tilt it until the bubble is seen to rest in centre. The + will then be superposed on whatever portion of the object is level with the eye of the observer.

If it be desired to lay out a line other than a level one, the arm at side of level is set to the desired gradient, or if this be over 10° the head carrying the level is moved to 10°, 20°, 30°, &c.

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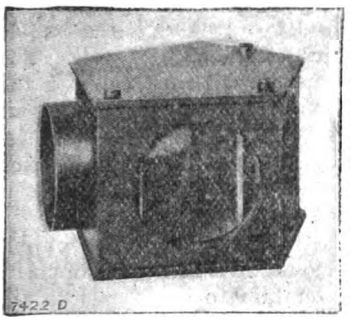
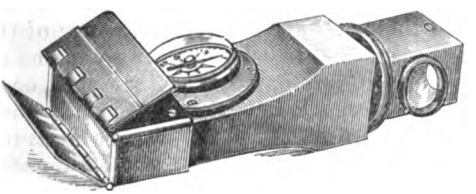
and the balance (if any) set on the arm. In this way a line can be ranged at any given angle, or by setting to 90° a vertical line can be plumbed with this instrument.



OPTICAL SQUARE.

The instrument shown is an optical square fitted so that it can be used with naked eye or for attachment to an telescope. The points to be "squared" are viewed, the one directly through the semi-transparent leaded mirror, and the other by reflection from this mirror and the silvered mirror, through the opening.



POCKET SURVEYING INSTRUMENT.

This instrument, which can be carried in the waistcoat pocket, will be found useful not only for rapid survey work, but as a companion in travelling.

It can be used as a hand level or gradiometer, for taking the horizontal bearings of objects, or angles between two objects, and for measuring angular heights.

The instrument consists of a metallic box of the form shown in the illustration, at the smaller end of which is mounted in a revolving collar a square box or tube (the sighting tube), through two opposite apertures in which the object can be viewed when the eye is placed opposite the aperture marked "Eye."

If the reflecting covers or flaps be opened and the instrument held so that the larger end of the box is illuminated by sky light, a scale and small spirit level will be seen projected upon the object.

To Use as a Level.

Turn the sighting tube at end till the side marked "Eye" is

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opposite the word "level" on the body. Open the reflecting flaps at other end, and hold the instrument vertically with the sighting tube below and look at object through the sighting aperture marked "Eye," and the scale and level will be seen projected upon the object.

Tilt the instrument backwards and forwards until the bubble be seen steady and opposite the zero in the centre of scale. The object on which the zero line is projected is then level with the eye of the observer, and as the divisions of the scale truly represent degrees and ¼ degrees on the landscape, the elevation or depression of any other object is represented by the particular division projected upon that object at the moment that the bubble is seen to be at zero.

Thus, if when holding the instrument level (the bubble opposite the zero line) the top of a mountain is seen to be opposite the division numbered 12. that mountain top subtends to the observer's eye an angle of 12° over the horizon.

If the elevation of the object is greater than 14° it will be convenient to first sight the exact spot on the object which corresponds to the zero—*i.e.*, level with the eye of the observer. Then the instrument can be tilted up till some one of the lower divisions, say the 10°, is opposite to that spot on the object, which has already been found to be level with observer's eye. In this way angles up to 24° or 28° can be measured. If still higher angles have to be measured the measurements must be made by successive steps.

If now the eye tube be turned a ¼ round till the word "Eye" on it be opposite the letter "H" on body, and the instrument be held vertical as when in taking levels, the scale will be seen projected as a horizontal scale on the object, and horizontal angles can be measured.

If the instrument be held horizontally, the compass being on top, the magnetic bearing of any object that is sighted through the sighting tube and brought opposite the zero line can be read off by the compass card.

To do this with any degree of accuracy the instrument should be laid upon some flat object, as a gate post or top of a wall, and turned until the object is seen with the zero superposed on it. The compass card will then give the bearing.

If it be desired to ascertain say the exact N. point of the landscape the instrument should be set till N. point of compass card is opposite the index. On looking through the sighting tube the point of landscape coinciding with the zero point will be the exact North.

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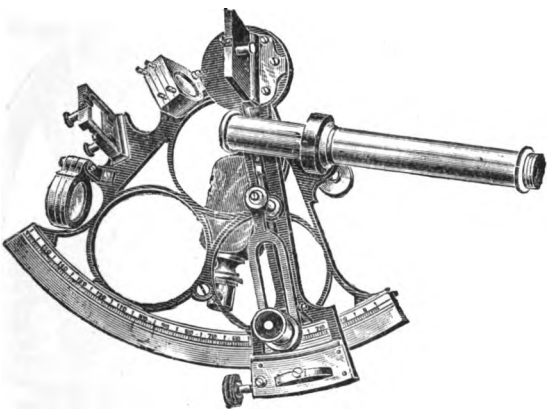
SEXTANTS.

The semi-transparent film already described (*see* p. 151) can be utilised in Sextants, and is found to be a great improvement on the half-silvered glass generally used, more especially as its adoption obviates the necessity for keeping the eyes in a fixed position.



DESCRIPTION OF THE GRUBB MINERS' DIAL.

In the construction of the miners' dial, the necessary distance between the fore and back-sights are entirely obviated, the Grubb sight only requiring 3 inches in length, so that the greatest space required is regulated by the diameter of the compass box, usually 5 or 6 inches. The accompanying figures illustrate the miners' dial with the sight attached, and with this construction angles can be measured up or down to 90 degrees, and may be read to 3 minutes of arc; and in both instruments the sight is hinged, so that back-sights and fore-sights may be taken by simply reversing that portion.

Fig. A. is constructed with the usual circular compass, outside vernier reading to 3 minutes, and the Grubb sight, mounted on an arc reading to 90 degrees both ways, with a vernier reading to 3 minutes. Fine adjusting screws are fitted for reading both horizontal and vertical angles.

Fig. B. differs from Fig. A. inasmuch as a trough compass displaces the circular compass box, and this is fixed under the horizontal plates, the ends projecting beyond the circumference, and an additional fine adjustment is supplied, so that the needle may be read with ease and brought to zero accurately The

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circular compass box being displaced, there is ample room for two large and sensitive levels which are fixed at right angles to each other.

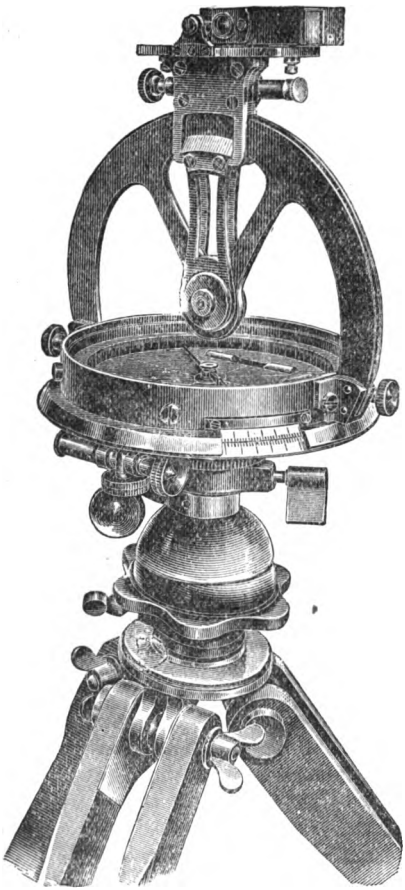

Fig. A.

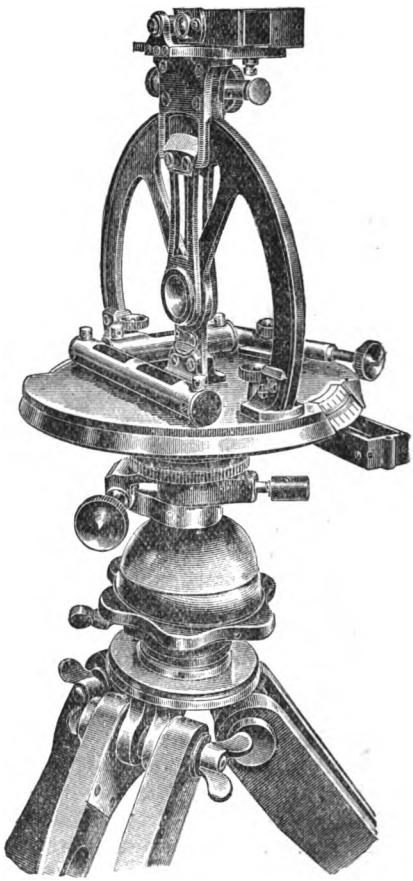

Fig. B.

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[*6th January*, 1904.]

Mr. Robert Cochrane, President, in the Chair.

The following Candidates were balloted for and duly elected :—

Robert M. MacFarlane as Member; and W. W. K Sparrow, S. M. S. Rajasooria, and F. W. Crofts as Associate Members.

Mr. E. C. H. Walker then read his paper on "Modern Foundry Practice."

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[3rd February, 1904.]

Mr. Robert Cochrane, President, in the Chair.

Further Notes on Sea Coast Erosion.

By R. G. Allanson-Winn, Member.

Since his paper, read to this Institution in May, 1903, the author of these notes has had opportunities of further investigation, and has also explained his views as to the effects of erosion below low water level to the Engineering Conference held in Westminster last June.* Very considerable correspondence has also taken place on the subject, but the soundness of the theory or the accuracy of the evidence adduced in its support have not been shaken.

As many of our Members may call to mind the theory is shortly this:—In all situations where the material is of a soft and easily eroded nature for a considerable depth below low water level, and where also the sea's advance is observed to be steady and continuous, no protective measures erected on the visible shore between high and low water marks will necessarily afford permanent protection, because the erosion going on below low water level causes a continual undermining of the works erected and a persistent advance of deep water. By actual observation we know that the sea-bed in the offing is deepened by the removal of material in many fathoms of water during storms, and we also know that there are many ancient sites of towns below which may now be sounded 5 to 6 fathoms of water.

The author claims to be the first person to draw attention clearly to this aspect of the foreshore problem, and he believes

* "Engineering," June 19, 1903

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that when the question is more generally understood, engineers will alter, or greatly modify, their practice in all situations where the conditions are such as the theory applies to.

The question will then not be, "how can I build the strongest wall on this soft and insecure foundation?" but "how can I best arrest the sea's advance for a few years so that the ultimate and inevitable loss may be minimised?" Or, to put it in a somewhat different light, we should not spend, say, £100,000 on a wall or other protective device designed to last 50 years if we know that the sea's action below low water level will without fail cause an undermining of the foundations in 10 years. In such a case an expenditure of possibly £20,000 would answer the purposes just as well, and, if there is any truth in the saying that a penny saved is a penny gained, the estate, Corporation, or other client would be the gainer to the extent of £80,000.

The fact that the invisible and inaccessible foe is working hard below low water level, and often at very considerable distances from the shore, and far beyond the reach of our walls and groynes, should give us every excuse for agitating for further scientific investigations. In many places—especially on the East Coast of England—the interests involved are, in the aggregate, very considerable, and we should insist upon knowing more before pledging ourselves to any particular expenditure which might involve an enormous waste of money.

At the risk of being accused of holding pessimistic views the author has given instances of places, both in England and Ireland, where, in his opinion, it is idle to expect protective measures—as at present understood—to offer anything beyond temporary relief.

Where questions of land reclamation are under consideration it is of the first importance to decide upon what places should be left alone, as by this means much useless and unprofitable outlay may be avoided. The owners of valuable property,

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unfortunately situated as regards the class of erosion we have been considering, are much to be pitied. Sympathy is extended to them, as it is to the owners of estates in the near neighbourhood of an active volcano; but it must be remembered that however strongly the advantages of State Aid may be advocated, Acts of Parliament will not change localities or alter geological stratification, and that Government grants will not stay the class of erosion to which attention is now called.

As recently pointed out, if the Government gave more encouragement to scientific investigation, and spent, say, £10,000 or £20,000 on further researches in this branch of science, properly belonging more to the geologist than the engineer, the real interests of the foreshore owners would be better served than they would by the reckless outlay of £1,000,000 on costly walls built on glacial drift, and destined in a few years to join the other masses of stone and concrete now lying at the bottom of the sea.

In 1899 the author called attention to the desirability of establishing a department which should be entrusted with the task of watching the foreshores, keeping reliable records, measurements, sections, &c., and generally increasing our store of scientific knowledge on coast line work. He believed then, and still believes, that the obstacles in the way of establishing such a department might be got over, and that the result would be, in the end, a saving of much unprofitable expenditure.*

About the same time, 1899, the British Association Committee, appointed to enquire into coast line changes, set to work, with the assistance of the Admiralty, to watch and report on the changes, &c., going on round the coasts of the United Kingdom.

* "Constructive Power of the Sea." Transactions Inst. C.E.I. Vol. XXVIII. Pp. 163–4.

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At the same time the author pointed out that the Committee, though actuated by worthy motives, could not expect to do much, as the coastguards were not in a position, from their training and equipment, to give the necessary information.

At the Southport meeting of the British Association the Committee's Report was presented, and an epitome was published which was so full of inaccuracies that the author felt compelled to draw attention to the fact that concerning certain places the statements were so misleading that it would not be safe or fair to place much reliance on the Report as a whole. We learn, for example, that on the Leinster Coast the Dublin, Wicklow, and Wexford Railway Line is in danger, and that two Martello towers have been destroyed by the sea, which is quite correct and very ancient history; and we are further informed that no beach material is anywhere removed. As a matter of fact the owner of the foreshore immediately to the north of Bray Harbour has for years past been selling the shingle and gravel at the rate of many thousands of tons per annum, and, as there is no Board of Trade or other prohibition, this serious denudation—forming as it does a most pressing danger to the railway line—is now going on steadily. It is estimated that not less than 20,000 tons of beach material has been thus removed within the past three years. Then, again, all down the coast from Greystones to Wicklow shingle and sand are taken in considerable quantities, and there is no prohibition here either, though the railway line was seriously breached in two places near Greystones a couple of years ago.

In the reference to Portrane, further to the north on the same coast, no mention appears to be made of the large quantities of material only recently removed during the construction of the Portrane Lunatic Asylum, though it is very well known that the contractors used much of the shore material, and that this denudation is to a great extent responsible for the present dangerous encroachment of the sea on

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the Coastguard Station. Surely in a report like this a strong point should have been made of this abstraction of material?

Proceeding round the south coast we come to Youghal, where we are told that the width of the breach which had to be closed was 50 yards. As a matter of fact at the time the embankment was started the whole of the low-lying land, to the extent of some 600 acres, was beneath the sea. The Great Southern and Western Railway Line was in the greatest danger—so much so that it was proposed to abandon the Youghal terminus altogether—and the embankment had to close a breach not less than 500 feet across.

On the Kerry Coast allusion is made to Glenbeigh, on the southern shore of Dingle Bay. Here the conditions are so remarkable that one looked for considerable information and comment, but there is, apparently, no mention of the important facts that since 1842 the sea has advanced 1,050 feet, that in 1897–98 the average encroachment for a distance of half a mile was over 60 feet, and that there is an immediate danger of the loss of over 500 acres, in which must be included several farms and much valuable building land.

Having been in charge of the shores at Glenbeigh, Youghal, and Bray as Superintending Engineer for several years past, and having acted as Consulting Engineer at Portrane, the author feels that he has a right to claim some knowledge other than that which could be acquired by a superficial observer, and that he may speak with some authority on matters of fact, measurements, &c., and he therefore took the liberty of publicly pointing out the errors and explaining that further enquiries had resulted in the discovery of similar inaccuracies in the English portion of the Report.

Of course mistakes will occur with Associations as with individuals; but when they do occur in considerable numbers—as in the present instance—no time should be lost

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in an effort to rectify them, and it is to be hoped that, in this case, the effort will be made, because there is no doubt that the foreshore erosion question is at the present time absorbing a great deal of public attention.

Of the making of reports, like books, there is no end; but the compilation of these guides to future action and expenditure is often undertaken without sufficient care, and it is to be feared that the necessary checking of the items to ensure accuracy is sometimes neglected. A report dealing with any special question may be issued and pass unchallenged, though full of glaring inaccuracies, unless it happens to meet the eyes of those who are in a position to correct the errors; more especially is this the case where the subjects dealt with are of an intricate or technical nature.

To say the least of it we may assume that, if a history of the coast line were now started, the British Association's Report would be largely used and quoted from, and as a result the narrative would be inaccurate and unreliable.

It is, of course, only natural that the names of the gentlemen serving on the Committee appointed in 1899 will be associated with the Report, and it is to be hoped that as soon as enquiries have been made and the author's statements are confirmed, some acknowledgment will be forthcoming of the services rendered in pointing out the inaccuracies.

The whole trouble has arisen from an error in judgment at the very start. When the Committee set to work in 1899 the members determined to rely to a great extent, if not entirely, on the reports sent in from various coastguard stations, and it would now appear that in a great many instances no trouble whatever was taken to verify these local reports, which were destined, later on, to appear collectively, as the Committee's Report.

It is indeed not easy to understand by what process of reasoning the Committee originally arrived at the conclusion

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that haphazard scraps of information thus collected could possibly advance the cause of science or be of any practical value. What one rather looked for was *accuracy as to facts;* but the published summary of the Report reveals such a complete travesty of even the facts that our hopes are dashed to the ground.

At all times—but especially at times of emergency—great care should be taken to found a report on evidence collected from thoroughly reliable sources. If we want to know about the weather we may ask a policeman, but we should be hardly justified in sitting down and writing a meteorological report for a scientific society on his unsupported opinion as to the probable changes for the month or week.

The author believes that no apology is necessary for introducing the question of the British Association Report into this paper, because it is of the utmost importance that the consideration of natural phenomena should be accompanied by accurate information as to facts.

For example, it is quite conceivable that a foreshore engineer called in, say, to advise on the East Coast of Ireland might be very much misled if he believed the following:—

"The headland at Howth and the northern side of Dublin Bay show neither loss nor gain. In the centre of Dublin Bay, however, from Poolbeg Lighthouse to Booterstown, inroads of the sea may accompany south-easterly gales. No changes are reported from Kingstown and Dalkey, but a rapid erosion is taking place between Killiney Bay on the north and past Bray Head to Six Mile point. The Dublin, Wicklow, and Wexford Railway Co. has built a sea-wall at the foot of part of the cliffs to the north, but hereabouts two Martello towers have entirely disappeared with the fallen cliffs, while part of the foundations of a third protrudes over the edge (1899). From time to time during the past ten years the railway has removed its permanent way inland, in places 10 feet to 30 feet,

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while at the date the Report was written the rails in places are only a few feet from the edge. No beach material is anywhere removed, and south of the Cable Rock groynes have been placed to protect the embankment."

It is unnecessary to make further quotations, for if the above, which forms portion of the epitome which has been in circulation since last November, is allowed to stand as a correct description of what is taking place in the neighbourhood of Dublin we shall be justified in assuming that it is not safe to use the Report for purposes of reference.

"Deep Sea Erosion."

When a foreshore engineer talks of deep water he usually refers to soundings below low water level, as works which are always under water, *even at low tide*, seem to him in deep water on account of the difficulty of carrying them out. But when the hydrographer speaks of deep water he may mean anything between 100 to 1,000 fathoms—nearly all his observations being effected by soundings. So that, for the purposes of this paper, deep sea erosion means erosion going on over any portion of the sea-bed below low water level. The author thinks it necessary to point out the distinction, because an attempt has been made to confuse matters by saying that water below low water level need not necessarily be "deep."

It will be observed that the theory only refers to places where special conditions obtain, and that no account is taken of those cases in which the sea, having for centuries exercised an erosive influence, suddenly, without any apparent reason, commences to retreat instead of to advance.

We have it on the high authority of Sir G. G. Stokes and Lord Rayleigh that waves exercise very considerable influence on particles in depths as great as 30 or 40 fathoms, but with-

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out going so far as this we have the very practical evidence of large masses of material consisting of :—

1. Travelling boulder shingle, with more or less strong indications of attrition.
2. Masses of rock with sharp edges torn from the sea bottom, not having such evidence of attrition.
3. Shells, sand, &c.

being carried in from depths below low water level, and that they come from depths below low water level is proved conclusively by the fact that they have deep sea-weed (Laminaria Digitata, &c.) attachments. Indeed, it is chiefly through the action of the currents and waves on the sea-weed attachments that the heavy masses are moved from their positions and carried on shore. Such removal of material from the sea bed necessarily deepens the water at the point where the transference takes place, and it can be mathematically proved that on a shelving shore or sea bottom no particle of material can be removed without a corresponding advance of deep water landwards.

Additional evidence of erosion in deep water is to be found in the sawing action of shingle on marl and soft sand stones at points below low water level, and this class of erosion may be observed at lowest low tide. We know also that there are many situations on the East Coast of England where 30 and 40 feet of water may be sounded below the sites of ancient towns which formerly stood on the cliffs over a mile from the present coast line.

If we take sections from the Holderness Coast of Yorkshire and continue them in an easterly direction, we find that at about a mile from the shore the 5 fathom line is reached, after which the gradient flattens out considerably, and the 10 fathom line is reached between 6 and 8 miles out, whilst the 25 fathom line is found at a distance of about 30 miles.

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On this particular coast we know that glacial drift, boulder clay, sand, and laminated clay overlays the chalk for a very considerable depth—100 to 200 feet; and we also know that the inland march of the sea has for years past been steady and continuous, and that it is now going on.

The general section has probably not greatly changed for several centuries, *i.e.*, as high water mark has advanced on the land so has the low water mark, and the loss below low water in the bed of the sea has also continued as the successive laminæ shown in section by dotted lines have been filched from the land. A further consideration of the subject from yet another point of view will possibly serve to strengthen the author's contention that the two erosions—the one *visible* above low water leve land the other *invisible* below that level—are going on simultaneously, but independently of one another, so that the checking of the one would by no means necessarily stop the other. Loss at high water may be temporarily checked, but erosion below the level of low water is always going on whenever the disturbing influences combine to cause denudation and erosion of the soft material, and this last-named influence is inaccessible and beyond the reach of any protective works as yet devised.

The author begs to draw attention to the shore at Bray, which has been in his charge for several years past. It will be observed that the advance of low water, within the short period of three years, has been very considerable. This shore, which lies immediately to the north of Bray Harbour, has been treated with nine low groynes, designed by the late Mr. Edward Case; and it must be admitted that since these valuable aids to sea walls have been added to the protective devices sand has come in where it was previously unknown, and the shingle bank has been so well

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distributed and kept in place that the wall itself—which is an important one, and holds up the high cliff on the top of which runs the Dublin, Wicklow and Wexford Railway Line—has not required underpinning since the groynes began to act some three years ago.

It will be inferred in this case that the groynes act as accumulators of sand and shingle, and the records of the shore show that this is so, and that the accumulation is maintained during certain months of the year when the shore may be said to be clothed. Storms from certain quarters then strip off this clothing, and the exposed marl is again left bare to the erosive action of waves and currents. It must also be noted that on this shore a neighbouring foreshore owner is selling the shingle accumulations to contractors and others at the rate of over 10,000 tons per annum, and that the backwash from the 20-foot sea-wall is also greatly against getting the full effective results out of the groynes.

There is a tendency in this country to ignore new ideas, and this is to a great extent brought about by the absence of interest in scientific investigation. It will hardly be denied that both in America and Germany advance in experimental science receives far more encouragement than it does over here. Considering our appalling ignorance on many subjects connected with sea phenomena—as evidenced by the diametrically opposite opinions of the highest authorities on matters which should, if properly investigated, be matters of *fact* and not of *opinion*—grants might well be made for the furtherance of carefully conducted experiments by individuals making the investigation and elucidation of the knotty problems their special aim and object in life. The investigation of scientific theories on matters affecting the nation's welfare may be best carried out by means of such practical tests. Slipshod reports based on haphazard scraps of infor-

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mation, picked up from sources incapable of furnishing any scientific data, are to be deprecated as misleading and inimical to the best interests of science.

THE PRESIDENT (Mr. Cochrane) said they were all greatly indebted to the author for his very interesting paper, which, as they were aware, was something in the nature of an extension to a former very interesting paper which he had read to them some time ago. It was rather a pity that they had not a better attendance of members, but the weather was so severe that it had deterred some from coming out.

The author deserved their thanks for drawing attention to some inaccuracies that occurred in the Report of the Committee of the British Association. That committee had been constituted to enquire into the erosion of the coast lines of the Kingdom. The statement that "no beach is anywhere removed" was absurd, because every summer they saw wagon loads coming up to Dublin by the D. W. & W. Ry. Co., in very large quantities.

While it was a matter of congratulation that the consideration of the question of deep-sea erosion was becoming a matter of national importance, and that it had been taken up by the British Association, it was a pity that greater pains had not been taken in the way of collecting the essential facts, which were absolutely necessary as a basis on which to form a satisfactory conclusion.

The author had given some very interesting particulars of the deep-sea erosion on portions of the Yorkshire coast. That county seemed to have suffered more from the inroads of the sea than most of the other counties on the Eastern coast, because, within comparatively recent times, whole towns have disappeared, such as Auburn, Hartburn, and Hyde in Yorkshire, and sites of other towns were now only sand banks some miles out in the sea.

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In Norfolk the villages of Eccles, Whimpwell, and Shipden have disappeared.

On the other hand, there are fortunately places in which the sea is retreating rather than advancing. We find towns such as Sandwich, Rye, and Winchelsea, and others which were once seaport towns, are now some miles inland.

It would be very interesting if it could be ascertained whether the area of land that has been recovered in this way equals or nearly approaches the quantity of ground that has been lost.

He thought the author was entitled to great credit, indeed, for the original way in which he had handled this matter of deep-sea erosion.

The author also deserved the thanks of the entire community for drawing attention to the very important question as to the waste of land that is going on around our coast and the problems involved in connection therewith.

While there were engineers who agree with the author's statement about deep-sea erosion being quite independent from surface action, others thought the motion of the waves was responsible for both the visible or surface action and the deep-sea erosion.

One of the objects of the author was to induce discussion, and if any member could add to their information, they would be glad to hear his views on this interesting question.

Mr. James Dillon said he would like to ask the author one or two questions.

With reference to the Bray shore, which he had been observing from time to time during the last three years—especially about the toe of the cliff—the carting of the gravel had been going on, notwithstanding injunctions and any amount of litigation to prevent it by the Railway Company, who were anxious to protect their line. Just about this time the Railway Company thought groynes, if properly placed, would save the

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coast; some of them were put up with very little good results. In more recent times the groynes referred to by the author were put up. He had been looking at these groynes, and did not observe any difference between the heights of the groynes on the north or south side.

What puzzled him was—if the groynes had been doing good work—why the Railway Company should, year after year since the construction of these groynes, be spending large sums of money on the wall.

There was another matter he would like some information on, and that was—if the groynes had been effective in protecting the shore, and increasing the height of the shore, why should low water be encroaching?

Another point was, that subsequent to the construction of these groynes an immense amount of damage was done about Greystones, and he wanted to know why the Railway Company adopted the suggestions of the author and put up groynes to the north of Bray, and refused to adopt similar assistance to protect the shore about Greystones, unless they considered that the groynes to the north of Bray were not working successfully.

During the engineering congress, held recently in London, there were papers read on the subject, and it was stated there by some engineers that it cost five times more money to protect land than to buy it. He would like to hear the author's opinion on this point.

The Council were always very glad to have papers of interest brought before the Institution, but they did not care for any paper to contain an attack upon public works. It was many years since he first joined the British Association. He thought it was only due to that Association to point out how they stood with regard to that report.

It was the practice, at the end of each year, to see what surplus funds they had on their hands after paying all expenses.

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They then apportion this to some subject. They have great difficulty in meeting all the demands. In this case the foreshore enquiry was started. It was only a private enquiry, and they got a few pounds from the British Association. It would be utterly impossible for a private committee, appointed by the British Association, to command funds to collect information of the magnitude that would be required to write a report with any degree of accuracy. The object of the report was to try, in a general way, to collect information, and to publish it so as to create interest in the subject. For that reason he would not like to see any great attack made upon the British Association for any inaccuracies in this report, which could only be considered as a preliminary report. He thought it was only due to say so much in that direction.

Mr. B. D. Wise said the paper, apart from the question of the Committee of the British Association, was a most interesting one. It brought a subject before them which required the greatest attention on the part of Engineers who had their railways and works adjoining the sea shore.

The author's former paper was a very interesting and instructive one on the subject of groynes.

He had some experience with groynes, having tried several experiments. The paper brought to his mind the shore at that developing watering-place, Whitehead. Here the shore near the railway was covered with boulders which were sunk in marly clay. He had these removed, and made a sea-walk with them. The result was that the sea took away the clay as fast as it could. He tried several ways to stop this. He put in groynes, the first of which he put in at right angles, and they were partly successful. He found that contractors were carting away the sand, but he was pleased to say the Board of Trade had promised to close the whole foreshore against removal. He was looking forward to the groynes to collect the sand.

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At another portion in Belfast he erected groynes formed out of old sleepers, which went out from 100 to 150 feet. He was perfectly amazed in two years to see the shore—on the north side of these groynes they filled up nearly to the top of the sleepers. He tried another stretch, running the groynes at an angle of 45° south. He found the gravel and sand came in from the south and filled up the groyne on the south, but left the north side quite bare.

There was a doubt if you got the right angle they were certainly one of the best systems for protecting our shores. He had protected about 1,500 feet. They put the groynes in both at right angles, and at 45°, and had succeeded in raising the shore 2 feet higher than it was. If they could have stopped the people taking away the sand they would have brought it a great deal higher.

He thought it was a pity the author had referred so much to the British Association; a few remarks would have been quite sufficient.

Mr. G. W. Lamplugh said he had listened to the paper with interest, and could bear testimony from personal knowledge to the accuracy of the statements that there was erosion going on below the level of low water. Of course it required no elaborate demonstration to prove that the Holderness coast line was retreating, the estimated rate being 3 feet per annum on an average. It was quite clear also that the foreshore was not getting broader, and therefore that the low-water ine must be steadily advancing. It was the duty of engineers to recognise this fact. He believed that the sea-floor was lowered by the action of marine life, as well as by direct scouring—that boring-mollusks and other organisms penetrated the clay and broke it down.

When engineers constructed protective works they did not expect the protection to last for ever. If it lasted for two or three generations it might still be worth attempting.

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It was well known on the Holderness coast that it was only the building land which was worth protecting. The annual interest on the cost of works for protecting agricultural land, exceeded the value of the land annually lost. It was therefore recognised that these defensive works can only be local and in the neighbourhood of valuable property.

After all, the point of practical consequence to the engineer was at what rate this deep-sea erosion went on. That might be ascertained by referring to old maps, which would show the former coast line. It would be quite easy to get the depth of the present sea-bottom below the old coast line.

With regard to the British Association Committee, to which the author had referred, the speaker suggested that the scope and constitution of this Committee had been misunderstood.

Mr. M. Purcell said during the last couple of years they had several interesting papers succeeding each other by the author on this deep-sea erosion.

It was a subject which appealed to all of them, to everyone who had a railway line or any other structure along the sea coast.

He wished to thank the author for the paper which he had put before them, and to ask a couple of questions, which, he had no doubt, the author would answer thoroughly.

Dealing with the coast of Bray, the author had stated that there were 20,000 tons of gravel removed during the last three years, and that the erosion was very great. It seemed to him that there was also a return there, because, as far as he could gather, when down at Bray the Harbour was useless owing to its being filled up with gravel and shingle that had been driven up into it. After a great amount of money had been spent on it, Bray Harbour was becoming useless for the purpose for which it was intended.

The author states that "waves exercise very considerable influence on particles in depths as great as 40 fathoms." Is

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that so? Is it wave motion, or is it tide, or rather current motion?

He asked the question because he had some experience of submarine work, and found that wave current did not penetrate down below. It was entirely surface action, and during a half gale, the action of the waves was absolutely unfelt at 30 feet from the surface. Therefore he took it that the question of wave action at 30 or 40 fathoms must have been a misnomer for current.

The author, in reply, said—With regard to taking notice of errors in reports, he could not help thinking that where errors are very clear, and are published, that they ought to be noticed by people who are capable of correcting them.

With regard to the Bray shore, he thought that carting away the gravel was contributory, and helped the deep-sea erosion. Where a man removed large portions of the shore material, he assisted the sea, in the same way as the submarine springs, currents and waves.

With reference to repairing the sea wall at Bray, he could assure them most positively that over the distance covered by the low groynes no repairs had to be done to the wall foundations since the groynes had been erected. There were no toes put into it. The wall was about 20 feet high, and the waves went right up over the top. There was pitching on the top, and the only thing that was done was to replace this pitching when it sank. Previous to the groynes being placed there, the foundations of the wall were constantly exposed.

With regard to putting groynes between Greystones and Wicklow, he had tried to get the Railway Company to put these down, for they would have had a better chance there than at Bray, as there was no wall to create a scour. He had pointed out to the Railway Company the difficulties that existed at Bray on account of the very high wall, and also

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from the removal of the material which went on in the immediate neighbourhood.

As he had pointed out, though the low water-mark was coming in, still, nevertheless, they had been able to maintain the shingle bank against the wall so well that no additional toe walls had been necessary.

He felt sorry that the British Association report was ever started at all. Coast Guards were not in a position to give them any information that would be of the slightest scientific value to them. They spent most of their time with their telescopes looking out for wrecks and smugglers, though it might have been expected that facts would have been correctly reported. The facts in the report were, however, hopelessly wrong about Ireland, and he believed the same thing occurred with reference to places in England. There were so many inaccuracies that the report was of no use at all. He believed if the history of the coast line was now to be started, that the British Association report would be quoted from. It was wrong, and it would be making wrong history.

He was not attacking the British Association, but he thought it was a pity that scientific gentlemen should give them wrong information. He did not want to attack anybody at all, but considered that he was well within his rights in calling public attention to publicly circulated inaccuracies.

With reference to Mr. Wise's experience with the slanting groynes, it was the same as his own. They collected material on the windward side and also on the lee. The reason for this was that they were slanting. The material collects in a way it cannot collect with groynes at right angles with the coast line. When the groynes are slanting, very much less stuff is washed back again than when the groyne is at right angles. A greater amount is collected on both sides of the slanting groyne than on both sides of the straight groyne, on one or

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other side of which scours are unavoidable. The curved groyne avoided sharp angles. He had tried the slanting groynes, and had found them in many places advantageous.

With reference to the people living on the Yorkshire coast, those living some distance inland were content to leave the matter to their grandchildren. They could afford to wait, but it was different with those owners of extensive flats, dependent for their protection on walls and embankments which, once broken down, allowed the flooding of very extensive areas by the sea. Examples of this were to be found at Romney Marsh, the Essex Flats, and the Wexford Slobs.

As regards the actual extent of land lost and gained, he was afraid some of the old maps were not very reliable, so that not much could be found out with any degree of accuracy by a comparison of ancient and modern maps. If a sufficiently lengthy period were considered, the loss and gain would probably be found to be pretty equally balanced.

With reference to the submarine action in deep water, it was rather difficult to argue on this point. He was not very clear on it himself. This was one of those cases where there was a necessity for scientific investigation, but the Government did not appear to be in favour of doing anything to assist.

It was different in Germany, where there were professors and assistants always trying to find out something new, and who welcomed any suggestion from earnest men. But in this country they were looked upon as nuisances, especially if they had anything scientific or useful to suggest. They wanted more investigation, as they were at present appallingly ignorant.

It was very difficult to keep harbours clear of sand. Arklow, Greystones and Bray Harbours, and many others on the coast, were all in a bad state. Large sums of money have to be voted for the construction of Harbours, and it would be

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readily admitted that much of this money was often wasted on injudiciously constructed works on ill-chosen sites. Our ignorance on these matters should induce a healthy desire to learn, and a special Department of State might well devote its whole attention to further scientific enquiries and investigations for many years to come.

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[*2nd March*, 1904.]

Mr. William Ross, Vice-President, in the Chair.

The following Candidates were balloted for and duly elected :—

Robert Inkerman Calwell, Patrick Harnett M'Carthy and Percy Herbert Stewart as Members; and John William Griffith, George Hastings Jephson, Jas. Gordon Lennox Hayes, Joseph Richard Pike McAlery and Joseph Alexander Rockett as Associate Members.

Iron, Steel, and Concrete Construction (*Le Béton Armé*).

By Mr. A. R. Galbraith, Associate Member.

(Plates.)

Part I.

Early History, Materials, Theory, and Practical Formulæ.

Introductory.

Constructions of this nature are also known by the generic names of armoured concrete, ferro-concrete, reinforced concrete, *et id genus omne*; but the above title has been chosen as one of the most correct and comprehensive. Ordinary concrete as a building material has many manifest advantages, being much stronger than brickwork, fire-resisting, frost, damp, and vermin proof; and when such concrete has been strengthened by the addition in a proper manner of an iron or steel armature, it can be readily understood that these advantages are at once considerably enhanced. Concrete itself came somewhat into vogue in this country at the

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beginning of the past century as a constructive medium, but owing to its unskilful employment several disastrous failures occurred, which, not unnaturally, created a prejudice against it, and retarded its development for some considerable time.

During the past sixteen years steel concrete construction has enormously developed upon the Continent and in America, so much so that it comes somewhat as a surprise to the British engineer, visiting these countries, to see the extent and variety of its application; in fact it would be difficult to name any branch of engineering or architecture to which it has not been already applied; and in bringing particulars of some of the most prominent of these systems to the notice of his fellow-engineers, the author ventures the hope that by the use of such constructions they will find the solution of many problems not so easily or cheaply solved by the ordinary methods. There are now some two hundred different systems extant, the materials used in almost every case being the same, their differentiation lying only in the details of their construction, the concrete being utilised where it will best display its characteristic force—*i.e.*, resistance to compression, and the metal, as a rule, being used only in tension. It can be taken as an average that the compressional resistance of concrete is about equal to ten times its tensile strength; hence the desideratum is to introduce the exact proportion of reinforcement necessary to make these resistances coincide.

Early History.—Concrete, with lime as a matrix, was used by the Romans 509 B.C., for in the Domus Vestalis at Rome a flat floor of twenty feet span was constructed without any intermediate supports, and the baths erected during the reign of the Emperor Caracalla, 211 B.C., contain excellent examples of concrete vaulting.

Two Englishmen, Parker and Whyatt, in 1795, by the calcination of argillaceous nodules, produced, it is believe for the first time, cement, a material now of inc

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able value in every ramification of the wide demesne of civil engineering; and to Napoleon the Great is credited the premier application of iron to concrete in the form of hoop-iron bonding, applied to the concrete used in the erection of the fortifications near Strasburg in Alsace Lorraine, about the end of the eighteenth century.

Initial Systems.—In 1861, Joseph Monier, a gardener of Paris, conceived the idea of strengthening some large cement ardiniéres by a metallic reinforcement of iron wire, and from this genesis was gradually evolved in 1868 the system bearing his name. Much about the same time Léon Coignet invented his famous *béton agylomèrè* and constructed with it some conduit pipes, floors and ceilings, reinforced by a double system of endless wiring at right angles to each other, examples of which were exhibited at the Paris Exposition of 1867. However, these early combinations, from their tentative character, developed unsatisfactory tensional weaknesses, and it can be said that it is only of recent years that through the cumulative results of exhaustive researches that these methods of construction have been brought out from the domain of experiment into that of practical engineering.

No more suitable material has yet been discovered for the efficient protection of iron or steel work from all oxodising, deteriorating and destructive agents than Portland cement concrete, but the proper disposition and economical correlation of the materials were beset with grave difficulties, and for a long time it was thought that the thermal coefficients of the concrete and the metal would be sufficient to destroy their adhesion, until the experiments of Bouniceau, Mesnayer, Hartig, Considère, Durand Claye, and others conclusively demonstrated that they were practically identical. This fundamental fact having been definitely established, the use of concrete steel grew apace, until it has obtained the increasingly prominent position that it at present occupies, and with

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the efflux of time it will, without doubt, occupy the premier position in modern constructive work.

First Introduction into England.—It was first introduced into England in the year 1897, when a retaining wall was constructed of sheet piling driven through 17 feet of hard sand and shingle at the northern end of the L. & S. W. R. Co.'s coal wharf on the River Itchen, Southampton, and the first building erected in armoured concrete in this country was a large flour mill at Swansea, at a cost of about 4½d. per cube foot, being about 15 per cent. in excess of the lowest acceptable tender for the same building in ordinary construction—both these structures being carried out on the Hennibique system.

It is now proposed to take into consideration the materials, their preparation, methods of application, and the general precautions to be observed in their use, as well as their coefficients, as indicated by numerous experiments by various authorities, and the values usually allowed and applied for such coefficients in the calculations for structures of this nature.

Materials.

The greatest care must be invariably exercised in the selection, admixture and application of all materials used in these composite constructions, and unremitting supervision must be given to all labour employed upon such works.

Matrix.—Too much emphasis cannot be laid upon the choice of the cement forming the matrix. It should be preferably Portland of the best class procurable, slow setting, of a true blue gray colour, and good age. It should not leave a residue of more than 10 per cent. in a sieve of 5,800 meshes per square inch, and should give a minimum tensile resistance of 400 lbs. per square inch of sectional area after seven days' and 500 lbs. per square inch after 28 days' immersion in water. Fresh cement or cement containing free lime must be absolutely prohibited, and the tests should continue almost daily, any

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cement not reaching the requisite standard being unhesitatingly rejected. No re-tempered cement mortar must on any account be used, for it has been indisputably established that after about two hours Portland cement shows a reduction of one-third to one-sixth of its original tensile strength, and in the case of Rosendale cement mortar a corresponding reduction of its tensile strength in about half of this time. Good cement must contain not more than 60 per cent. of combined lime, and but a trace of magnesia.

Cements invariably expand in water and contract in drying, and according to the experiments of M. Considère, the results of which were published in *Le Génie Civil*, February 4th to 25th, 1899, severe interior stresses are set up in armoured concrete structures where rich concrete mixtures are used, owing to the shrinkage of the latter during the first eighteen months if exposed to the air, or a corresponding increase of bulk during that period when used in submarine work. For neat cement this amounts to 2 mm. per metre, which shows that rich cement mixtures should be avoided as much as possible.

Aggregate.—The aggregate should be composed of coarse sand of different sizes, especially where impermeability is essential. If the gravel or ballast contains sand, these must be separated and mixed again in their correct proportions. Broken stone can be substituted for gravel or ballast, but it must be of a very hard and gritty nature with a minimum of mica. All these materials must be most scrupulously clean, and entirely free from all traces of any argillaceous or earthy matter. No material that fails to pass through a ¾-inch mesh sieve must be permitted to pass into the concrete. Good refuse clinker has frequently been used in the composition of the aggregate, and, although not so impervious as concrete made with fine gravel and sand, it is well adapted for foundations and for protecting drains and other conduits. Where it is required to be thinly laminated, and of a finer

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quality, as in fire-resisting floors, it must be crushed and sifted. According to some experiments made with clinker concrete (not breeze) in 1896 it was found to possess a greater compressive resistance than that made with Thames ballast. In all buildings intended to resist fire, limestone, even of the hardest quality, must on no pretext whatever be allowed in the aggregate.

Concrete or Béton Proportions.—The usual proportions of the concrete for buildings, with their floors, pillars, beams, &c., is 4 and 5 to 1, and in pile work, or work that must be impervious to water, 3 to 1; but whatever the proportions decided upon, the strength of the concrete will be materially affected by the thoroughness of the mixing.

Mixing.—Recent experiments in this respect have conclusively demonstrated the superiority of mechanically mixed concrete over hand mixed ditto by at least 18 per cent, and, according to Professor Ira O. Baker, good concrete can be strengthened nearly 100 per cent. by prolonged trituration and attrition of its constituents. In mixing by hand it is well to increase the proportion of cement by ½ cwt. to 6½ cwts. It is important that the concrete should be in a plastic condition. It should be used fresh, in small quantities at a time, and well rammed and punned until the moisture is evenly distributed. Care should be taken that the concrete should not be too liquid, because if so its compressional resistance is reduced, accompanied by cracks in the setting; and should it be *vice versa* its proper setting will be proportionately affected. Another excellent method in mixing is to gauge the aggregate, filling its interstices accordingly; then add a concrete mortar, say 1 of cement to 2 of sand, with a margin of about 10 per cent. for faulty mixing.

General Precautions.—Where concrete work has been discontinued before the completion of the structure, the surface of the old work must be well serrated with a cutting tool,

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and cleansed from all foreign matter before resumption. Pure fresh cement grout must be then poured on the surface of the work before commencing, care being taken to well pun the old work to the new so as to form an efficient bond. All concrete should be used up before work is suspended, and any left over must not be again used. Fresh concrete work should be freely watered for some days, and if this cannot be done, it should be kept in a moist state by a good blanket of wet sand, especially if exposed to heat, as the sand will greatly lessen the chances of peeling or cracking that may be set up with increased temperature. Large surfaces of concrete should be cut up about every ten feet with half-inch wooden strips, so as to allow for expansion and contraction. No centres, moulds, props, or struts should on any account be moved until the concrete has sufficiently set, and no load should be placed on a green floor. The moulds and shuttering are generally removed after a few days, but it is advisable to allow at least a month to elapse before the entire removal of the temporary supports, when the structure will be then ready for the tests.

It is a good arrangement to turn concrete arches in layers; as each layer is put in place it will assist the centre, which can therefore be of a lighter construction. To protect an arch from percolation a skin of 1 to 1 cement and sand about an inch thick applied to the extrados will suffice. This is preferable to using asphalte, which is liable to flow towards the weep holes, choking them up, the wall thus having to sustain a water pressure, which had, perhaps, not been taken into consideration.

Metal.—As a high coefficient of elasticity is of value, the iron should not be too soft, and for a similar reason a hard steel is preferable. Siemens-Martin's steel is to be given the preference over Bessemer, owing to its purer and more uniformly good quality. The breaking strain under tension

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should be 28 to 32 tons per square inch of sectional area, with an elongation of not more than 20 per cent. in 8 inches. All rust should be thoroughly removed from the metal, as owing to its slight coherence there is a tendency for the latter to slip through the enveloping concrete through the medium of the former.

Coefficients of Materials.

Compressional Resistance of Concrete.—The compressional resistance of concrete is, according to M. Christophe, equal to 700 lbs. per square inch, and it is well in calculating for concrete submitted to direct pressure to allow, say, a factor of safety of 2 as the minimum for structures of a permanent character exposed to heavy moving loads, or the vibration and shocks set up by machinery, &c. This would give 350 lbs. per square inch for columns, piers, arches, walls, &c., subject to absolute compression; and for girders, beams, floors, roofs, &c., having to sustain the action of tensile forces, he adopts the higher figure of 430 lbs. Thirty per cent. must be allowed off these figures when breeze is used in the aggregate.

Experiments have shown that the strength of concrete considerably increases with age, as much as 6,000 lbs. to the square inch having been reached with 3 to 1 concrete upon the expiration of one month. The results of some experiments by M. Considère, published in *Le Génie Civil* some few months ago, upon the behaviour of concrete and armoured concrete columns in direct compression, showed that in piers of concrete *in toto*, tested to destruction, the first evidence of collapse appeared in a swelling about their middle diameter, and as the load increased so the swelling augmented, until the limit of resistance and cohesion being attained the concrete bursts—the upper portion descending upon the lower, crushing the whole into a heap. He, therefore, reinforced a similar pier with a winding of wire,

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amounting to 0.035 per cent. of its volume, and this pillar sustained a compressional load nearly 4½ times greater than the other one, thus indicating that the armature should be applied as near their circumference as is consistent with their safety and appearance.

Tensile Resistance of Concrete.—Ordinary concrete will bear an elongation of not more than $\frac{1}{10000}$ of its length without rupture, its tensional resistance being thus only $\frac{1}{10}$ of its compressional ditto, and when properly combined with steel of $\frac{1}{1000}$ without fissuring. However, this tensile resistance is not of great importance, as it is a general rule that this resistance is a neglected factor in all calculations for these constructions.

Shearing Resistance of Concrete.—The resistance to shearing may be taken as 20 lbs. per square inch—the safe minimum; but on this particular property of concrete but little is known, there being insufficient data, owing to the comparatively few experiments that have been made in this direction. However, it has been absolutely established that beams and slabs having a double armature in the form of transverse rods, as well as longitudinal ones, have a much greater resistance to shearing stresses than those composed of single longitudinal rods only.

Adhesion of Concrete to Metal.—This is so intimately involved with the nature of the armouring, the fine quality of the cement, the size of the aggregate, the quantity of water, &c., that it is impossible to give any figures that would be reliable for general application. Professors Baushinger and Ritter estimate it about 570 lbs. per square inch, and it has been shown to be as high as 630 lbs. per square inch. M. Considère, in some recent experiments on concrete mixed at 300 kilogrammes per cubic metre (3 to 1), found that an increased percentage of water multiplied the sliding resistance from 71 to as much as 157 lbs. per square inch proportionately

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to the quantity of water employed, and that it increased to 256 lbs. if the rolling scale was permitted to remain on the rods. The adhesion between the concrete and the metal proves upon investigation to be quite sufficient for ordinary practice.

Modulus of Elasticity of Concrete.—The value of this modulus with regard to all static computations of reinforced concrete is of the greatest importance; but the results of experiments have been so diversified, differing from as much as 6,000,000 to less than 1,000,000, that it is far from yet being established—in fact it is extremely doubtful whether it will ever be satisfactorily defined owing to the varying intensity of the stresses acting on each constituent particle of the concrete. However, as nearly all authorities take no cognisance of the tensile resistance of the concrete, what is actually necessary is to discover the ratio existing between the modulus of elasticity of concrete under compression with that of the steel in tension. This has been mutually agreed upon by M. Christophe and Professors Brik and Hall as 1 : 10, and is the ratio adopted in the building code of Dusseldorf and other large towns in Germany, where much concrete steel work is done.

Armature.

Compressive Resistance.—This is far in excess of that of the concrete; but having taken 700 lbs. as the maximum for this constituent, it is not necessary to take into consideration the compressive resistance of the metal.

Tensile Resistance.—As the various coefficients of the concrete have been given a low value, so does M. Christophe adopt a low limit for the metal, in order that the great advantage of a relative proportion should be maintained, and it has been found that in the majority of experiments carried to destruction that the failure was caused, not by the crushing

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of the concrete, but owing to the limit of elasticity of the metal having been exceeded.

The values therefore adopted are for:—

Iron 8,500 lbs. per square inch.
Steel 12,800 ,, ,, ,, ,,

Shearing Resistance.—For our purpose this can be assumed as follows:—

Iron from 6,800 to 11,300 lbs. per square inch.
Steel ,, 10,000 ,, 17,000 ,, ,, ,,

Limit of Elasticity of Steel.—The limit of elasticity of the armature is not of crucial importance, as its ratio to that of the concrete has been fixed at 10 to 1; but we may take for this:—

Iron 33,000 lbs. per square inch.
Steel 36,000 ,, ,, ,,

Considerations regarding Armature.—It can be easily understood that the sizes and shapes of the reinforcing members are all but as numerous and varied as the systems themselves; but it can be taken as a general rule that the simpler the arrangement of the armature commensurate with the work it will have to perform the better. The round rod, which is greatly used, has these advantages—it is the cheapest, occupies the minimum space, and admits the concrete more readily into the interstices than those of more complex sections. Small sections are preferable to large ones, as they distribute the stresses more equably throughout the mass of concrete, at the same time giving a larger surface for adhesion to each square inch of section; they also offer greater facilities for bending into any required shape, and are formed with ease into a trellis. Compared with this, rolled sections have special advantages for joints and junctions, and that with them an entire self-supporting structure can be erected before the concrete is applied. Against this is the fact that rolled sections together with large rods increase the labour

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of placing them in position. Although theoretically the longitudinal members are only taken into consideration for the cross-bending strains, experiments have shown that in beams and floors, where the armature has been disposed transversely as well as longitudinally, have given a greater resistance than those with the longitudinal reinforcement only, though the same percentage of steel was used in both cases. This demonstrates the superiority of the trellis and similar forms of armouring connected together with transverse ligatures, for not only is the area of adhesion augmented, but there is a decided counteraction to the shearing stresses. In this respect "expanded metal" makes an ideal trellis, though, weight for weight, it is more costly than rods. This extra cost is practically eliminated by the saving of labour in fixing. It has also been proved that the adhesion of the concrete to flat bars is not equal to those of square section.

Variations of Temperature.—Some concrete steel constructors, owing to the close coincidence of the coefficients of expansion and contraction of the two materials, ignore the stresses liable to be set up by variations in temperature. But this is not good practice. These stresses should be allowed for wherever possible by the provision of expansion joints to the various structures, especially to those of large area exposed to the action of the sun and other thermal agencies—in straight pieces to have supported ends rather than fixed, to provide hinges to arches, and other precautions that suggest themselves to the engineer during the progress of the work. M. Christophe deals very thoroughly with this question under Paragraph No. 624, "Influence de la Température," page 707 of his book *Le Béton Armé.* He says:—

"Il est possible que le béton ne puisse suivre que dans une faible mesure les variations diurnes, mais les variations saisonnières l'affectent certainement." "Il va de soi que cette influence dèpend de la situation des pièces. Dans un

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grand nombre de constructions l'action des variations de température est négligeable. Il en est ainsi pour les ouvrages intérieurs des bâtiments (planchers, piliers, cloisons), ainsi que toutes les constructions établies sous le sol, comme les fondations, les voûtements, les canalisations souterraines, etc. Dans les ouvrages exposés aux intempèries, tels quel les façades et terrases des bâtiments, les ponts, les soutènements, et revêtements, etc. Il est au contraire indispensable, si l'en veut éviter des mécomptes sérieux d'apporter les plus grand soin à'en prevoir les effets aussi biens dans l'établissement du projet que dans l'exécution et ce, d'autant plus que la pièce considérée présente une plus faible épaisseur et se trouve exposée plus directement."

THEORY.

It is to be regretted that space will not permit of anything approaching adequate treatment of the theory of these fascinating constructions, but a few of the most practical formulæ, given by M. Christophe, Professor Hatt and Major Winn, R.E., will be mentioned.

Of the theories involved in the application of concrete steel, according to M. Planat, the most rational examination arranges the practical cases into three degrees :—

Firstly.—With a light load the concrete and the metal have a mutual adherence subject to a common deformation.

Secondly.—Under a medium load the steel acts as tension members built into the supports at the extremities.

Thirdly.—With a heavy load the reinforcement becomes as suspended cables beneath the structure.

From these premises formulæ have been deduced for beams and floors.

Slabs.—*In the Monier system, the theory of which was first enunciated by Koenen in Germany, and afterwards by

* See Proceedings Inst. C. E., Vol. CXXXIII. Page 376.

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Beer in this country, the slabs are calculated out by the formula—

$$\tfrac{1}{6}\, rbd^2 = \text{M}.$$

when $r = 430$.
b = breadth.
d = depth.
M = moment of resistance.

and the proportion of metal being 1 per cent., placed not less than half an inch from the tension edge.

A fixed slab is stronger by one-half than one merely resting on its two ends. Should it be square and supported on every side, it has double the strength of one supported on two sides only. A rectilineal slab supported on all sides, whose breadth is less than twice its length, owing to the extreme supports not affecting the centre, can only be taken as being supported along its longer sides. To find the depth of the span for square slabs supported on all sides—

$$d' = \sqrt{\tfrac{1}{2} d^2} = \tfrac{7}{10}\, d.$$

To find d see depth in accompanying table.

Fixed or continuous slabs—

$$d'' = \sqrt{\tfrac{2}{3} d^2} = \tfrac{4}{5}\, d.$$

Should the four sides be fixed—

$$d''' = \sqrt{\tfrac{1}{3} d^2} = \tfrac{3}{5}\, d.$$

Table of Monier slabs supporting a super-load of 1½ cwts. per square foot, with an armature in trellis of 4 steel bars per foot run of bearing equal to 1 per cent.

Span in feet	Depth in inches	Diameter of Resistance Members in parts of an inch	Diameter of Partition Rods in parts of an inch
3	2	$\frac{9}{32}$	$\frac{5}{32}$
4	2½	$\frac{5}{16}$	$\frac{5}{32}$
5	3	$\frac{11}{32}$	$\frac{6}{32}$
6	4	$\frac{13}{32}$	$\frac{7}{32}$
7	4½	$\frac{7}{16}$	$\frac{7}{32}$
8	5	$\frac{7}{16}$	$\frac{7}{32}$
9	6	$\frac{1}{2}$	$\frac{1}{4}$

The depth of the slabs being given to the nearest half inch.

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The depth of no slab should be less than two inches, and when the spaces exceed nine feet, it is more economical to support the slabs by beams.

Beams.—For beams simply supported the straight armature is sufficient; but if fixed, the bent form of reinforcement is preferable. Where the condition of the forces acting on the beam may be taken as something intermediate between the above conditions, the combination of the straight and curved form, such as the Hennibique beam, is the best, although some method of vertical armouring must be devised in the form of stirrups or ligatures to resist the shearing stresses, especially in beams of considerable depth.

To arrive at the section of this vertical armament it is necessary to consider that the shearing stresses are equably divided between the curved rods and the stirrups.

Reaction at the supports $= R.$
The shearing resistance $= S^r.$
Length of span $= l.$
Depth of beam $= d.$
Number of stirrups with two legs $= y.$

The section of each rod $= \frac{R}{2} \times \frac{1}{2S^r y} \times \frac{l}{4d}$, as given by Major Winn.

Neutral Axis.—As the result of the experiments and researches of Professor Hatt, it has been demonstrated that a beam 12 inches deep, with a steel reinforcement of $1\frac{1}{4}$ per cent., placed 2 inches ($= \frac{1}{6}d$) from the lower sides, the neutral axis was 4.36 inches from the top, and when reinforced with $2\frac{1}{2}$ per cent. was 5.47 inches from the upper surface. From this, with an armature of 2 per cent., the neutral axis would have been 5 inches from the top, or midway between the upper surface and the reinforcement; the concrete below the armature not entering into the calculations being looked upon only as a protection to the metal. So that with 2 per cent. the axis is, for all practical purposes, in the middle of the beam

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with the metal in tension, and the concrete in compression in a proper balance.

For the investigation of concrete steel beams three formulæ are proposed by Professor Hatt in the *Engineering Record* of May 10th, 1903.

Using the symbols hereunder :—

E^1 = modulus of elasticity of concrete in compression.

E^2 = ,, ,, steel.

ω = sectional area of steel.

t^s = tensile resistance of steel.

c^r. = safe compressional resistance of concrete.

x = ratio of distance of neutral axis from compression edge to depth.

u = ratio of distance of armature as above = 1 when the concrete in tension is neglected.

M = moment of resistance.

Taking Fig. 1 as the stress diagram :—

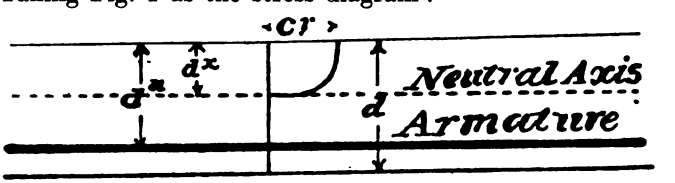

Fig. 1.

we have— (1) $2\,c^r\,x = 3\,\omega t^s$.

(2) $M = bd^2\,[\frac{5}{12}\,c^r\,x^2 + \omega t^s\,(u-x)$.

(3) $\omega = \frac{E^1}{E^2}\,(u-x) = \frac{2x^2}{3}$.

Taking $\frac{E^1}{E^2}$ as 10, and $u = 1$, the following are obtained :—

when $\omega = \frac{bd}{100}$, $x = \cdot 32\ d$.

$\omega = \frac{bd}{50}$, $x = \cdot 4\ d$.

$\omega = \frac{bd}{30}$, $x = \cdot 5\ d$.

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From the first formula the tensile resistance of the steel can be obtained, and if the bending moment is known, the depth can be computed from the second formula, the breadth being assumed at any convenient figure.

T *Beams.*—T beams are greatly used throughout Germany in the designing of floors, &c., and the undermentioned method is the most simple one for their solution. This method is also employed as a check on the Hennibique system and other monolithic floors of a similar character.

Granted the following assumptions :—

(*a*) The tensional resistance of the concrete being eliminated, the whole of the tensile stresses are taken as being concentrated at the axis of the armature.

(*b*) The portion in compression is represented by the table of the T submitted to a uniform pressure.

Let λ = breadth of table.

g = thickness.

The compressional resultant $= c^r \lambda g$,

And the tensional resultant $= t^s \omega$, both being equal to one another.

M equalling the amount of resistance equals M^1, the bending moment, then the compressional resultant acting at the centre of the table

$$M^1 = c^r \lambda g \left(d - \frac{g}{2}\right);$$

or

$$M^1 = t^s \omega \left(d - \frac{g}{2}\right), \text{ as Fig 2.}$$

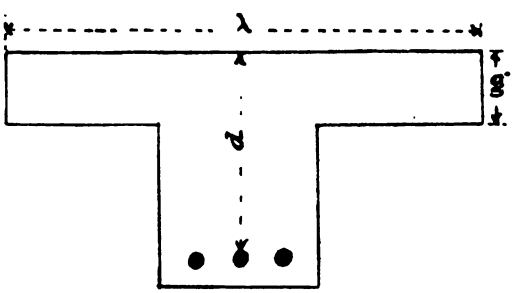

Fig. 2.

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Given M^1, g, λ, c^r and t^s, the depth d of the armouring, as well as ω can be found—

$$\omega = \frac{c^r}{t^s} \times \lambda g,$$

$$d = \frac{g}{2} + \frac{M}{c^r \lambda g},$$

t^s being taken at the usual values, and c^r at 350 lbs. per square inch.

However it should be pointed out that the thickness of the table in many cases can hardly have any affinity to the depth of the beam, for theoretically the table can be reduced until it attains the least possible thickness.

Arches.

The armature, which ranges in a Monier arch from ½ to 1 per cent., and to a maximum of 2 per cent. in the Melan, is placed as close to the extrados and intrados as possible; care being taken that there is enough concrete externally for adequate protection, and that the reinforcement is carried well into the abutments, in order to ensure no failure at the springing. As in beams, a vertical armature is sometimes introduced either as a stirrup (Figs. 25 and 33) in the Hennibique, or as a ligature in the Melan (Fig. 43), to counteract the shearing stresses.

Hinged arches are preferable, with hinges both at the springing and at the crown, for precisely similar reasons to their preference in ordinary concrete or masonry construction, and when this method is adopted a double reinforcement should be used; while the thickness of the concrete should be slightly increased at the haunches, where the bending moments attain their maxima. In arches up to 70 feet span this increased thickness can have a uniform distribution from the crown to the springing, as in fixed arches.

Numerous methods for arriving at the thickness of armoured concrete arch rings have been applied, but the least complex

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is that of Monier, it having been adopted in the erection of some 500 bridges on the Continent.

With concrete 1 to 3, a pressure of 430 lbs. per square inch, equal to 28 tons per square foot, is well within the limit of safety, being largely in excess of the coefficient used with brick arches, and the tensile stresses being taken by the steel, we are no longer compelled to the restriction of the line of resistance to the centre third.

The axis of the arch is traced as a parabola, corresponding approximately to the line of resistance caused by a uniform load assumed to pass through the centres, both of the crown and the springing.

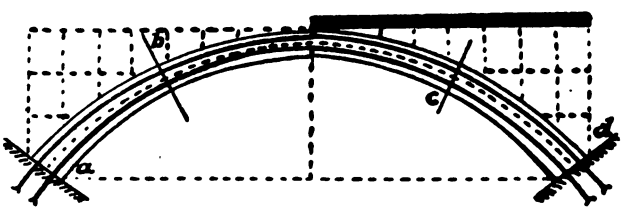

Fig. 3.

The horizontal thrust being found together with the thrust at the springing at per unit of breadth in the usual way, and dividing these values by 430 we obtain—

H = horizontal thrust at the crown.

Z = ,, ,, ,, springing.

$\frac{H}{430}$ = thickness of the crown.

$\frac{Z}{430}$ = ,, ,, springing.

Then treating the arch for dead loads—

If w^1 = unit of weight for dead load.

w = ,, ,, ,, live ,,

l = span.

f = rise

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we have—

$$\text{Horizontal thrust} = H = \frac{(w^1 + w)\, l^2}{8f}$$

$$\text{Thrust at springing} = Z = \sqrt{\left[\frac{(w^1 + w)\, l}{2}\right] + H^2}.$$

The dead load should be reduced to a minimum and distributed as uniformly as possible. In order to do this, skeleton spandrils should be employed, the weight of the road being conveyed to the arch ring by columns suitably braced if they exceed 10 feet in height, *vide* dotted lines, Fig. 3.

A bending moment is also set up by the live load reaching its maximum at the $\frac{1}{4}$ span at b and c under a half load, as in Fig. 3.

This bending moment $= \frac{1}{64}\, wl^2$, and at these points the thrust $= \frac{1}{16}\, \frac{(2w^1 + w)\, l}{f} \sqrt{1 + \frac{4\, d}{l}}$.

The thickness of the ring at b and c is such that the compression set up by the thrust added to the c^r, found by equating

$$\tfrac{1}{64}\, wl^2 = \tfrac{1}{6}\, c^r d^2$$

is not in excess of 430 lbs. per square inch.

The increased depth thus found is given at these critical points so that the arch is as Fig. 4.

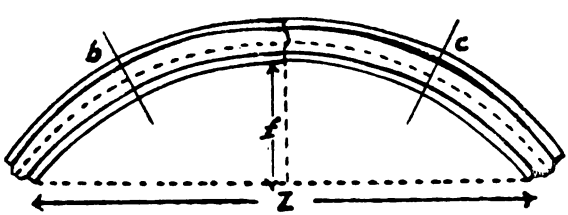

Fig. 4.

WALLS.

To calculate the proper quantity of steel per cent. for walls, it is necessary to adopt a percentage θ, then taking a proper

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working coefficient c^r for the concrete, minus the armature, to augment it, so that—

$$c^r = c^r \left(1 + \frac{E^1}{E^2} \times \theta\right).$$

$\frac{E^1}{E^2}$ being taken as equal to 10,

then $$c^{r1} = c^r (1 + 10\ \theta).$$

In walls the percentage of the vertical reinforcement can be usually taken from ½ to 1 per cent. Hereunder is a table of coefficients for different percentages of steel from ½ to 5 per cent.

Percentage of Steel	Values of c^{r1} in lbs. per square inch $c^r = 350$
½	370
1	390
2	430
3	465
4	500
5	530

Pipes.

In pipes submitted to external pressure the strains are compressional under a uniform load; the longitudinal rods are, therefore, placed outside the rings or spirals (Fig. 5),

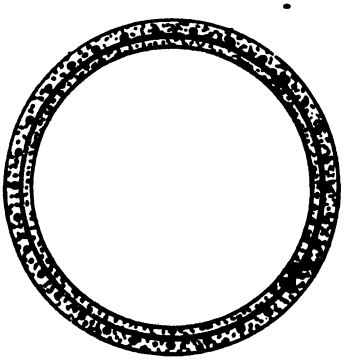

Fig. 5.

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the percentage of metal varying generally from ½ to 1 per cent. This armature is to prevent any deformation of the pipes which may be set up by an unsymmetrical load; but if this is absent the reinforcement is superfluous.

The thickness of the pipe is calculated by assuming that the whole of the compression is taken by the concrete.

So let P = pressure per unit,

D = diameter,

then at both sides of the pipe

$$P = \tfrac{1}{2} D \times p;$$

and if the coefficients for compression $= c^r$,

the thickness of the pipe $= \frac{P}{c^r} = \frac{D \times p}{2c^r}$,

c^r varying with the percentage of steel as given for walls.

In pipes exposed to internal pressure, such as those for conveying water and gas, the strains are tensile. For strains of this nature the concrete is not taken into consideration,

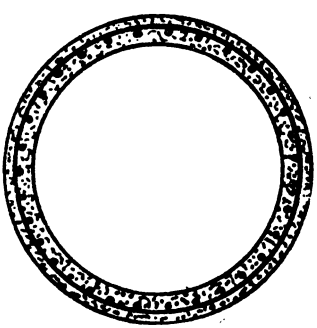

Fig. 6.

and they, therefore, must be taken up by the reinforcement, the section of which must be chosen accordingly, spacing the circular or helicoidal rods about every 6 inches or any other desired distance apart. In this case the longitudinal rods following the direction of generatrices are placed within the

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rings or helicoids, these latter again being superimposed near the exterior surface of the pipe (Fig. 6).

Let P = pressure per unit,

D = diameter,

then the tensile strain $T = \frac{1}{2} D \times p$.

If l = spacing of transverse armouring,

ω = sectional area of transverse armouring,

then $t^s \times \omega = T \times l = \frac{1}{2} D \times p \times l$,

from which the section can be computed.

Large pipes have a double armature, for a description of which see the Bonna System.

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[*6th April*, 1904.]

Mr. ROBERT COCHRANE, President, in the Chair.

PART II.

DESCRIPTION OF THE PRINCIPAL SYSTEMS, WITH EXAMPLES.

MONIER SYSTEM.

The Monier System, which is the oldest of the different systems, has been, and is, applied to floors, beams, arches, domes, reservoirs, pipes, conduits, bridges, &c. The metallic skeleton is simple, being a trellis formed of two lines of horizontal rods at right angles to each other, the lower or longitudinal rods (*a*), named resistance members, being spaced about 3 inches apart, and connected to the upper or partition rods (*b*) by .25 inch wire ligatures at their intersections (Fig. 7). These ligatures are only a temporary expedient for the purpose of keeping the rods in position until they are embedded in the concrete. The section of these rods vary with the load to be supported, and when the load is very heavy several combinations of this nature are used together, the partition or transverse rods as a rule being about three-fourths the diameter of the resistance ones, although cases occasionally occur when the former may be considered as having to sustain similar strains to the latter; they should then be of the same diameter.

Floors.—Floors are constructed under ordinary conditions with a minimum thickness, exclusively of any wearing surface, of 1½ inches for flat floors and 2 inches for arched ones; while 3 feet for the former and 8 feet for the latter have been adopted as the minimum spacings. Arched floors usually have a rise

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of only $\frac{1}{10}$th the span, and in the instance of a heavy superload the thrust is therefore considerable. This can be taken up by tie rods at the extreme bays, or by horizontal terminating girders anchored to the walls. Care should be taken that the centre line of a series of arches should coincide with the vertical centre lines of the supporting girders, as the slightest divergency will cause an appreciable torsional tendency unless the girders are embedded in the concrete. The slabs comprising the floors weigh about 12 lbs. per square foot for every inch in depth, and to make them properly fire-resisting the armature must be at least an inch from the surface of the concrete.

Roofs.—In roofs, slabs of reinforced concrete are substituted for the rafters, purlins, and usual framings, the horizontal thrust being counteracted by suitable tie rods. With regard to thickness, the same remarks apply to roofs as well as to floors, and roofs up to 60 feet span have been constructed on this system. Floors and roofs of circular reservoirs are armatured by a square or angular trellis work, as before described, and reservoirs are made almost invariably circular, so as to obviate the weakness of the joint obtained with those of rectangular shape.

Pipes.—Pipes from 6 inches to 9 feet diameter, and from 1 to 2 inches thick, are made by machinery on this system with concrete, reinforced with an iron or steel network of a similar description to that previously mentioned. They are made either with a collar or an ordinary spigot and socket joint, being perfectly water-tight and almost as smooth on their inner surface as if made of glass. These pipes, above 12 inches diameter, will compare, as regards cost, most favourably with earthenware ones of corresponding dimensions, and are, therefore, very much cheaper than those of iron. Pipes of this construction have been in use for the ast twenty years in several towns in Germany, both for

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sewers and water and gas mains, and have given every satisfaction.

Domes.—Several domes have been erected on the Monier System, notably those of the Conservatore at Dresden, they being 57 feet in diameter, 32 feet high, and 3 inches thick, glazed between the ribs with glass.

Bridges.—A great number of highway and railway bridges have been built on the Continent on this method, one being constructed as far back as 1890 at Wildegg, having a span of 130 feet, with a thickness of 6 inches at the crown, without iron girders, and is still in a first-class condition.

It is a remarkable fact, but this system is the only one that has been patented in Germany, every attempt to introduce others meeting with comparative failure.

Cottancin System.

The Cottancin System is named after its inventor, Jean Paul Cottancin, who initiated it in the year 1889. This system is applied to buildings in their entirety, and, although somewhat elaborate and complex, in its application it has met with unqualified success, no structure out of the very great number in which it has been adopted having yet failed.

The metallic ossature consists of a network, or, more correctly speaking, a basketwork, of steel wire, about $\frac{1}{5}$th of an inch thick, of varying mesh, corresponding to the different loads the finished structure will have to sustain; the general rule being—the heavier the load the smaller the mesh. It was found, however, that the closeness of this meshing presented difficulties, as it was apt to prevent the concrete from completely filling the interstices; it was therefore deemed advisable to increase the diameter of the wire at the points of heaviest loading instead of reducing the size of the mesh as heretofore. This meshing can soon be learnt by a workman of ordinary intelligence, although now special machinery

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has been devised for its preparation, and the whole of the wiring in every part of a structure constructed on this system is so intimately connected up and interwoven with the object of an equable distribution of the various stresses, so as to form an homogeneous whole. Fig. 8 shows the lattice pattern reinforcement, and Fig. 9 the continuous skeleton on this method.

Foundations.—These are formed in caisson work of the inverted box type, divided up into cellular compartments, and as a substitute for piling have proved remarkably economical and effectual, especially in the case of fluid subsoils, such as various kinds of river alluvium. At Tunis, where the rebuilt portion of the modern town is contiguous to the harbour, and occupying the site of an ancient lagoon, the silt of which in places reaches the depth of over 100 feet, it was found by experiment that ordinary foundations were only capable of bearing a load between 31 and 32 lbs. per foot super without irregular subsidence, whereas the Cottancin raft supported a super load of 777 lbs. per square foot with only 0.008 inch of uniform subsidence. This load was subsequently increased to 17 per cent. beyond the official maximum, equalling 1,711 lbs. per super foot, the subsidence then amounting to only $1\frac{5}{16}$ inch, and was still uniform; and it was only on increasing the load beyond the official maximum by 100 per cent. that signs of unequal subsidence became evident.

Floors and Ceilings.—M. Cottancin here utilises a system of beams, called by him *èpines contreforts* (spine reinforcement), Fig. 10 showing section through same, where the concrete is framed about a metal skeleton, placed on edge to obtain the maximum bending resistance. The wires of these beams project sufficiently to be interwoven and connected to those of the horizontal network of the floors and walls, both above and below, so as to obtain the greatest immobility. This arrangement can be compared to a kind

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of lattice (see *A*, *B*, *C*, *D* and α, β, γ, δ, Fig. 11), its upper and lower members being connected uninterruptedly by flat diagonals; α, β, being in compression, are replaced by the mass of concrete; while γ, δ, being in tension, are replaced by the wiring of the reinforcement. These beams are generally 14 inches in depth and 2 to 4 inches in breadth; they are also provided with lower flanges (*A*, *B* Fig. 12), which are intended to carry the light slabs of reinforced concrete comprising the ceiling. The beams are frequently made on the ground, and lifted bodily into place, intersecting one another as shown in Fig. 13, some parallel to the walls and others diagonal, making a pleasing and artistic arrangement for decorative purposes. Some of these beams, 14 inches by 4 inches in cross section, have been used to support floors of over 39 feet span. The ceiling slabs are moulded prior to erection, and shaped to fill the interspaces between the beams. They are generally strutted up against the underside of the floor by small props in the position *C*, *D*, Fig. 12, being lowered and fixed in their proper position, *A*, *B*, Fig. 12, so soon as the concrete is properly set in the superincumbent flooring; sometimes, as an alternative, ordinary shuttering is substituted. The floor reinforcement is then prepared *in situ*, or added previously formed, as already mentioned, and interwoven with or attached to the loops left in the armature of the beams and walls for this purpose. Care should be taken when the ceiling slabs are used as centres for the flooring that their upper surfaces are suitably prepared by a layer of oiled paper or otherwise, to prevent their adhering to the fresh concrete of the underside of the floor. Floors are usually 2 inches thick, the network being arranged about one inch above the bottom of the slab, at the sides, and woven prior to the concreting. This network also has a distinct sag towards the centre of the span, which slightly increases the strength of the slab. These floors are of ample strength when the

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spaces do not exceed 3 feet 6 inches, if wiring $\frac{1}{3}$th of an inch thick is used, and the total thickness of the mass is $1\frac{3}{4}$ inches. Some tests carried out by the French Government have proved that great strength is obtained by this system. In one instance, two slabs were tested, one reinforced, and the other of concrete only. The dimension of each slab was about 3 feet $3\frac{3}{8}$ inches square, and about $1\frac{3}{4}$ inches thick. The reinforced slab sustained a distributed load of $2\frac{3}{4}$ tons, with nearly half an inch deflection, before gradually collapsing; while the plain one, with only a distributed load of a little more than half a ton, suddenly gave way.

Walls and Partitions.—The question of the construction of walls and partitions has been ingeniously solved by M. Cottancin. Concrete itself is not altogether suitable for vertical partitions, as the softness of the fresh material, and the difference in density between the sand and cement hardly allow the forming of a thoroughly homogeneous mass. M. Cottancin, therefore, utilises hollow bricks in combination with the metallic reinforcement. These bricks are vertically perforated, through which perforations pass the reinforcing wires, these wires being fixed to horizontal flat bars along the top and bottom bed joints (Fig. 14). The size of these bricks is usually $8\frac{5}{8}'' \times 2\frac{3}{8}'' \times 3\frac{1}{8}''$, having a single row of four perforations $1\frac{3}{16}''$ square to each brick, laid flat. Bricks twice this width, with a double row of four or more perforations, are occasionally used, but for partitions the former sized bricks are preferred, and arranged on the double cellular system for external walls. These perforations, as soon as the reinforcement is in position, are filled up with cement grout, both for the purpose of protecting the metal and acting as a key. Walls of the façades of houses five or six storeys high have been erected on this system, with double walls of brick, each about $2\frac{3}{4}$ inches thick, reinforced with the spine construction previously described for floors.

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Columns, &c.—Columns, piers, pillars, &c., are constructed with a continuous metallic reinforcement of steel wire ¼ inch diameter applied spirally near the outer circumference, and spaced ¾ inch to 1 inch, centre to centre. Vertical bars are also introduced to increase their resistance against lateral flexure, and it may be taken as a general rule that columns should not exceed 27 times their diameter in height without bracings.

Roofs.—Ordinary roofs are formed with a double slope of reinforced concrete, and a similar ceiling, each with a connecting reinforcement, this constituting a series of lattice beams as A, B, C, D, E, F, Fig. 15. Light rafters are then placed upon the supports, carrying a roofing of zinc or other material. In Mansard roofs the entire complication of framework or truss construction is eliminated. Dormers and skylights can be constructed in such roofs without the slightest danger of any weakening of the completed structure. Arched roofs of small rise have the roof and ceiling slabs carried on curved and longitudinal intersecting ribs, two methods of such arrangement being shown in Figs. 16 and 17. Little rise is given to these ribs—in one instance a roof of 59 feet span only having a rise of 16 inches, and another one of 46 feet span having the lesser rise of 14 inches. These arched beams or ribs are frequently made with reinforced brickwork.

Domes.—Domes have been constructed on this system, notably one at the Chateau Orfrasière. This dome is 52 feet in diameter at 125 feet above the ground, and supported on 18″ × 18″ reinforced brick piers.

Bridges, &c.—Bridges, reservoirs and other forms of engineering construction have been erected with considerable success on this system; but it is in the domain of architecture that it has more especially demonstrated its marked superiority, the nature and arrangement of its materials permitting in

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the hands of a skilful architect a sufficient latitude in obtaining decorative and constructional effects impossible in ordinary practice.

Examples.—At the Paris Exposition of 1900 the Pavilion of the Republic of San Marino, which stood at the foot of the Eiffel Tower, was erected on this system. It was the most economical building in the Exhibition, costing but 6 francs per cubic metre, equivalent to about 1.7d. of our money per cubic foot of air space, being about the cost of a similar structure in timber. This building was successfully subjected to severe tests, both for stability during construction, and subsequently at the period of its demolition some few months afterwards, when some very instructive results were obtained.

The house No. 29 Avenue Rapp, Paris, was erected from designs of the architect, M. Lavirette, on this system, and was deservedly one of the six houses premiated in the annual competition instituted by the Paris Municipality, called the "Concours des Façades." The whole of the building, with the exception of the stone employed for the front of the ground floor, was of the Cottancin construction. The vertical portions or walls are constructed of steel reinforced brickwork; the horizontal portions or floors of steel reinforced cement, combined with similarly reinforced brick, and the inclined portions or roofs of both the materials in combination with the same system. The street front of enamelled stoneware is reinforced with the usual wire ties connected to the basketwork reinforcement of the main building, thus forming a continuous metallic ossature throughout the whole of the walls, floors, roofs, and façade, and giving a complete structure of a fire-resisting nature of remarkable strength. On the ground floor the main walls, usually carrying the superstructure, are replaced by 9″ × 9″ reinforced pillars of brick. The walls of the staircases and lift are

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built of similar work, 4½″ thick, rising from the basement to the roof, the walls confining the living and other rooms being constructed of two thicknesses of 2½″ Cottancin brickwork with an intervening air space. The chimney breasts are here replaced with hollow walls built of two thicknesses of 2¾″ reinforced brickwork, with the space between divided off by cross partitions to form flues of regular dimensions, these walls taking their portion of the weight of the floors, as the rest; the other hollow walls being used for the various heating and ventilating flues, as required. The flooring is free from all timber except the parquet. The roofs are formed of sloping walls of reinforced brickwork, with brick and cement dormers attached to the metallic reinforcement, and, being constructed on the cellular system, provide attic rooms, which are comfortable both in summer and in winter, and are fire-resisting, no timber being used in their structure. The weather surface of the roofs and flats is formed of a 2-in thickness of armoured cement, and on the street side of the house in the Avenue Rapp is covered with ornamental tiles embedded in the cement and attached to the reinforcement. On the courtyard side at the rere, the slopes are left in cement without any further covering, and no lead, zinc, or other metal is used for the weathering or gutters, all these being formed in cement.

No lintels of any kind are employed over the openings, the reinforced brick wall above forming its own lintel by reason of the vertical tie afforded by the reinforcement. The façade, with the exception of the lower storey, is constructed of enamelled-coloured stoneware reinforced and connected to the armature of the front portion of the building behind. It should be noticed that the wide arch which forms one of the principal features of this façade has its abutment against a window opening, which is itself unsupported and projecting from the wall of the main building. By these means the

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architect has been enabled to carry out this very bold and striking design, and to bring forward at the same time the heavy projections which ordinary construction would scarcely have permitted.

The economy in cost, compared with that of ordinary construction, in the case of this building is estimated at 22 per cent.; whilst the saving of space gained by the suppression of the chimney walls and breasts and in other portions of the structure is found to be about 60 feet super.

This system was introduced into England in 1902 by Mr. Arthur Vye-Parminter, an architect of Paris, it being applied in the construction of the foundations, walls, suspended gallery, and caissoned dome of the Wesleyan church of St. Sidwell's, Exeter, at a cost of £3,000, Messrs. Commin & Coles of that city being the architects. A rain water tank with reinforced brick caisson bottom and sides 4½″ thick was carried out at Newark-on-Trent for Messrs. Simpson & Co., and the caisson brick foundation bed and boiler settings for the new heavy boilers at the Pumping Station on Duck Island, St. James' Park, London, S.W., were also executed on this system for H.M. Office of Works.

Expanded Metal.

"Expanded" metal, or the Golding System, as named after its inventor, Mr. J. F. Golding, has attained wide employment and recognition, not only in this Kingdom and the Colonies, but also in various parts of Europe and the United States of America. As a substitute in lieu of the network of the other systems it is admirable, and the saving of labour connected with its use compensates for the extra cost of the "expanded metal"; in fact, as a reinforcement for floors, roofs, and arches it can hardly be excelled.

It consists of expanding by special machinery sheets of

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various metals into a lattice or mesh work (Fig. 19), with diamond-shaped meshes and strands of practically any desired sizes and thicknesses. The cutting and opening out of these strands are effected by the machine in a single operation, and metal treated in this manner possesses greater rigidity and covering power than that of the original sheet operated upon without any waste of material. The expansion effected exceeds the initial breadth of the sheets from 2 to 12 times, in accordance with the size of the meshes and the depth of the strands formed, being achieved without any diminution of weight or reduction in the first size of the sheets.

Expanded metal is now made in lengths not exceeding 16 feet, and, as the metal is stronger the long way of the mesh, the sheets should be laid in this direction between the supports. This material has been found to increase the strength of floors and arches from 8 to 11 times, and to diminish the amount of concrete required by 75 per cent. The arrangement of the mesh forms an excellent key for the cement or concrete, and it is impossible for there to be the slightest slip within the concrete through the imposition of any heavy load or extraordinary strain upon it. In the selection of the kind and weight of the metal due regard must be paid to the load to be sustained, the distance between the supports, and the nature and thickness of the concrete proposed to be used. The metal generally preferred is mild steel, combined with coke breeze concrete, this latter being only about 60 per cent. as strong as stone ditto.

The usual size of the mesh employed in concrete construction is 3 inch, experience having demonstrated that metal of 3 inch mesh, with $\frac{1}{4}'' \times \frac{1}{8}''$ strands, gives the best results with slabs of 3 inches in thickness. The joints are formed by the overlapping of one complete mesh, and hereunder are given the sizes used with the 3 inch type:—

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No. in Co.'s Catalogue	Size of Strand	No. in Co.'s Catalogue	Size of Strand
31	$\frac{1}{4}'' \times \frac{1}{4}''$	30	$\frac{3}{4}'' \times \frac{3}{16}''$
9	$\frac{3}{16}'' \times \frac{1}{8}''$	11	$\frac{3}{16}'' \times \frac{3}{16}''$
8	$\frac{1}{4}'' \times \frac{1}{8}''$	15	$\frac{1}{8}'' \times \frac{1}{8}''$
10	$\frac{1}{4}'' \times \frac{3}{16}''$	7	$\frac{1}{4}'' \times 16\,G. = \frac{1}{16}''$ (about)

The present prices range from No. 15 at 1s. to No. 10 at 2s. 5d., and besides the above three-inch mesh other meshes are manufactured from $\frac{1}{4}''$ to 6″ in size.

Floors.—A good, strong, light floor is composed of slabs (Fig. 20) armoured with about one-half per cent. of metal, weighing on an average from 25 to 30 lbs. per square foot, supported on rolled steel joists, which, if desired to be fire-resisting, must be surrounded with $\frac{3}{8}$ inch mesh expanded metal lathing rendered with ordinary plaster (Fig. 21). A table taken from the company's catalogue with reference to these floors is appended.

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Working Load per superficial foot of Floor	Distances between Joist Centres	Thickness of Slab	Type of Metal Embedded	Approximate weight of Flooring Slab per foot super	Class of Concrete	SECTIONS OF STEEL JOISTS Suitable for the undermentioned Spans, Centres, and Loads. Spans between Walls or Mains									
Cwts.	Feet apart	Ins.	Ins.	lbs.	1 of Cement to 4 parts of aggregate	10′	12′	14′	16′	18′	20′	22′	24′	26′	28′
$1\frac{1}{2}$						Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Dwellings, Offices, &c.	5	3	$3 \times \frac{3}{16} \times \frac{1}{8}$	19	Coke Breeze -	$6\frac{1}{4} \times 3\frac{1}{8}$	$7 \times 3\frac{3}{4}$	$7 \times 3\frac{3}{4}$	8×4	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$				
Do.	6	$3\frac{1}{2}$	$3 \times \frac{1}{4} \times \frac{1}{8}$	22	Do.	,,	,,	8×4	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$	10×5				
Do.	7	4	,,	33	Broken Brick and Clinker or Coke Breeze	$7 \times 3\frac{3}{4}$	,,	,,	$9\frac{1}{2} \times 4\frac{1}{2}$	10×5	12×5				
Do.	8	$4\frac{1}{2}$	$3 \times \frac{1}{4} \times \frac{3}{16}$	37		,,	8×4	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$	12×5	12×5				
2 Public Buildings -	4	3	$3 \times \frac{1}{4} \times \frac{1}{8}$	19	Coke Breeze -	$6\frac{1}{4} \times 3\frac{1}{8}$	$7 \times 3\frac{3}{4}$	8×4	$9\frac{1}{4} \times 4$	$9\frac{1}{2} \times 4\frac{1}{2}$	$10 \times 4\frac{1}{2}$	12×5	12×5		
Do.	5	$3\frac{1}{2}$	,,	29	Coke Breeze and Broken Brick or Clinker	$7 \times 3\frac{3}{4}$	,,	,,	$9\frac{1}{2} \times 4\frac{1}{2}$	$10 \times 4\frac{1}{2}$	12×5	12×5	$15 \times 5\frac{1}{2}$		
Do	6	4	$3 \times \frac{1}{4} \times \frac{3}{16}$	33		$7 \times 3\frac{3}{4}$	8×4	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$	12×5	12×5	$15 \times 5\frac{1}{2}$	$15 \times 5\frac{1}{2}$		
3 Warehouses, Factories, &c.	4	4	$3 \times \frac{1}{4} \times \frac{1}{8}$	37	Broken Brick or Clinker and Furnace Ashes	,,	8×4	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$	12×5	12×5	$15 \times 5\frac{1}{2}$	$15 \times 5\frac{1}{2}$	$13\frac{13}{16} \times 5\frac{1}{2}$	$15\frac{3}{4} \times 6\frac{3}{32}$
Do.	5	5	$3 \times \frac{1}{4} \times \frac{3}{16}$	46		,,	$9\frac{1}{4} \times 4$	$10 \times 4\frac{1}{2}$	12×5	12×5	$15 \times 5\frac{1}{2}$	$15 \times 5\frac{1}{2}$	$13\frac{13}{16} \times 5\frac{1}{2}$	$15\frac{3}{4} \times 6\frac{3}{32}$	$15\frac{3}{4} \times 6\frac{3}{32}$

NOTE.—These figures are for continuous slabs (equal to fixed) over beams, and for fire-resisting work an extra inch must be added to the depths given in the Table.

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Arched Floors.—The Channel Arched Floor System (Fig. 22). This patented system is one of the best and most economical methods of floor construction for the heavy loads met with in warehouses, factories, &c. It is constructed with spans between the mains of from 12 to 25 feet, with arches formed of curved steel channels (6 inches wide, weighing about 12 lbs. per lineal foot), and varying from 4 to 8 feet apart, according to the load to be carried. On these channels, between the joists, the concrete is built up to the floor level. The amount of rise in the arches approximates as nearly as possible to one inch per foot of span, and floors can be constructed to carry super loads up to one ton per square foot, with an average dead load not exceeding 40 lbs. per square foot of floor area.

Ceilings.—Suspended ceilings are used in this system, being fastened to the under side of the steel joists in the following manner:—Steel joists clips are attached to the lower flanges of the joists, which in their turn carry the bar hanger attachment for the ceiling bars running at right angles to the joists; to these again, at suitable intervals, are fixed the ceiling clips, to which is affixed the expanded metal lathing rendered with ordinary plaster. These ceiling bars are generally from $1'' \times \frac{1}{4}''$ to $1\frac{1}{2}'' \times \frac{1}{4}''$ in section, spaced in parallel rows, about one foot apart; the clips and bar hangers, being of mild steel, can be adjusted to suit any size of flange, &c. These flat ceilings can also be hung beneath the long span floor arches, through the medium of hanging rods placed at suitable distances apart, their upper ends being hung from the curved channels, while the lower extremities are attached to the ceiling bars. In arched floors the ceiling, should it be desired, can follow the contour of the arches by being hung in a curved form by means of special clipping contrivances. The total weight of these ceilings ranges from about 9 to 12 lbs. per foot super.

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Partitions.—Thin solid partitions, when used in combination with the above floors and ceilings, are constructed with vertical tension rods, ¼ inch diameter, at intervals of about 1 foot apart, and secured to the ceiling bars or joists and floor girders by metallic clips. Between or in the face of these rods, as the case may be, sheets of expanded metal are interlaced and fastened by wire ligatures, thus forming a key for the plastering, which is applied in the usual way. When these partitions have to be fixed to wooden joists and floors, the extremities of the partition rods have hook and eye terminations for securing them to the woodwork by means of convenient screwing devices, or another way is for these rods to have eyes at both ends to receive ordinary wooden screws for this same purpose. These partitions are usually 2 inches thick, and weigh only some 18 lbs. per square foot of surface area. In comparison with a half brick wall there is an economy of about 66 per cent. of space, and more than half the weight. In places where it is inconvenient or impossible to use tension rods for the support of the lathing a rodless partition can be erected by means of patent removable extension studs, employed temporarily to keep the lathing and rough frames for doors and other openings in the partition in position, the partitions being fixed to the floor, walls, and ceiling, through nails or hooks driven into same, to which the lathing is securely wired. These studs are set at about 12 inch centres, a quick setting plaster being applied on the side opposite these temporary studs, which are afterwards removed as desired, as the plastering proceeds.

Hollow Partitions.—Hollow partitions are formed with light angle-iron uprights or standards, metal lathing, and plaster or cement on both faces. They generally take up about 5 inches of space, so, therefore, little economy is effected in this way, and they weigh about 22 lbs. per foot super.

Expanded metal is also applied in the construction of sewers,

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water conduits, and other archiform structures with advantage, and is also used for fire-resisting casings for stanchions, columns, girders, and other numerous forms of building construction.

Example.—A retort house, 86 feet long, 56 feet wide, and 32 feet high, was erected at the Dublin Gas Works about 4 years ago. A skeleton building was first constructed, and then enveloped with expanded metal lathing and plaster, 3 inches thick, the lathing being attached to horizontal tension rods $\frac{3}{8}$ inch in diameter, stretched from stanchion to stanchion. This, when completed, formed a light, strong, and economical structure, perfectly suited for the purpose for which it was designed, and requiring but a slight foundation.

Hennibique System.

This system was first applied by M. Hennibique about 1892, and since then so steady and continuous has been its development that at the present time it is one of the most widely-known systems in the world, works to the value of the large sum of over £4,800,000 having been executed by this method alone from its first introduction. Its distinguishing characteristics are its compactness and simplicity, it being employed in the construction of entire buildings from the foundations to the roofs. The armature is a combination of straight and curved bars of circular section varying from 0.39 to 1.57 inches diameter. In the slab these curved bars alternate with the straight ones, as depicted in Figs. 23 and 24, the straight portion of these bent rods being equal to about one-third of the span; but in the thin slab the bent rods are dispensed with altogether. All the free ends of the rods in this system are bent back or cleft at their extremities as an extra precaution in gripping the concrete.

Stirrups.—The most salient feature of this system are the elongated U-shaped stirrups (Fig. 25), made of wrought

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hoop iron 1.18 to 2.36 inches wide and .0945 of an inch thick. They are designed to assist in withstanding the shearing stresses, the concrete having but a low shearing resistance as elsewhere mentioned. They are placed at proper distances along the beams and floors, being passed underneath and in contact with the tension bars, and are continued vertically through the height of the beam, being turned slightly over and outwardly at their ends, so as to form a key to the concrete. In beams the upper ends of these stirrups project a little above their surface into the under part of the floor to act as a tie, and distribute the strains well into the whole structure. Care should be taken that the inner curve of the stirrups is in every case in actual contact with the under side of the bars, and their prescribed position must invariably be strictly adhered to.

Tests of beams have been made with and without the stirrups in order to demonstrate their value, which had been, and is, considerably disputed. These two beams were made with exactly similar quantities of materials, but the one with, and the other without, the stirrup reinforcement, and were subjected to identical loads until they manifested signs of collapsing. The beam without the stirrups was the first to betray this weakness, the concrete breaking away in lumps from around the tension bars, leaving them exposed; whereas with a similar loading the beam with the stirrups showed only small vertical fissures and hair cracks insufficient to jeopardise its stability. These experiments have subsequently been several times repeated with very much the same results, thus demonstrating that the action of the stirrup does, to a modified extent, increase the shearing resistance of the beam.

Beams.—The reinforcement of the beams is similar to that of the slab, with the exception that the cranked bars are placed directly above the straight bars, and in the same vertical plane, the latter bars running parallel to the under

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side of the beam, and embedded about one inch in the concrete. These cranked bars acting in conjunction with the straight bars and stirrups, which stirrups are placed closer together at the ends of the beam near the uprights, where the shearing stress reaches its maximum, Fig. 28 constitutes a statical triangle, which may be compared with a timber beam trussed with iron rods and brackets (Fig. 26). Fig. 27 shows a section through A, B resisting the maximum bending moment. Fig. 29 shows the respective positions of the bars and stirrups and the manner in which any bending strains of the lower bars are transferred to the upper portion of the beam, and changed and distributed as compressive strains into the mass of concrete. The depth of these beams is usually $\frac{1}{12}$th to $\frac{1}{15}$th the span. When head room has to be taken into consideration, and the depth of the beam correspondingly reduced, compression bars can be introduced into the upper portion of the concrete for the purpose. Beams constructed on the foregoing principles will support the heaviest loads over large spans—43 and 47 feet being not unusual; and a beam constructed at the Cattle Wharf at Princes' Jetty, Liverpool, has a clear span of 64 feet. Some floor beams tested in a public building in New York gave remarkable results. These beams were 8 inches wide by 20 inches deep in section (including the 4-inch continuous floor slab), and 24 feet long (supported only); the reinforcement, consisting of four $1\frac{1}{8}$-inch rods, was tested with a distributed load of 600 lbs. per super foot on the floor, and gave a deflection of only $\frac{13}{32}$ inch. After unloading the permanent deformation, resulting from a load four times in excess of that the beam was designed for, was $\frac{1}{16}$ inch only. This, compared with a steel beam of similar depth with strength sufficient not to exceed the elastic limit, would have an estimated deflection of $1\frac{3}{4}$ inches.

Floors.—For floors with small span with ordinary loads,

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the slab form before described is sufficient ; but for large floors the usual method is to divide the space into squares of about 10 to 12 feet by means of main and secondary beams supporting the floor slabs on all sides so as to make them continuous, and, consequently, reduce their thickness. These beams in their turn are supported by pillars (Fig. 32), where the arrangement of the floor is very clearly given. Fig. 30 is a section of the main beam constructed to receive the heaviest loads ; while Fig. 31 is the secondary beam connected up to the main beam, both beams in their turn being built into the floor slab.

All bars are supported by stirrups for a short distance from the beams, but the stirrups are discontinued as the centre of the floor is approached, as they are not then required. As in the Monier System, these bars are sometimes crossed diagonally where lateral stresses are at all likely to be set up. The beams and the floor taken together thus form a monolith, the whole series being joined together so as to form a continuous homogeneous structure without scarf or joint. These floors are well adapted for loads of 1.83 to 3.66 cwts. per super foot ; and a floor at the Co-operative Society's Warehouse, Newcastle-on-Tyne, designed to carry a load of 6 cwts. per square foot, was satisfactorily tested to .9 cwts. per foot superficial.

Arched Floors.—Fig. 33 shows the general arrangement of the reinforcing bars and stirrups in arched floors. In the Palais des Beaux Arts, Paris, there is a floor of this description, with a span of 18 feet, having a 9 inch rise, 18 inches deep at the haunches, and 3 inches thick at the centre. These floors have been constructed for spans up to 60 feet in the clear.

Walls.—Partition walls, and now and again external walls, are armoured with longitudinal and vertical rods—the former being placed in the centre of the wall, with the latter disposed equidistantly on either side and tied to the opposite

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side by stirrups (Fig. 38). Walls constructed in this manner are light and of slight thickness in comparison with their height, hardly ever being more than 9 or 10 inches thick in the highest buildings.

Retaining Walls.—These are usually provided with suitable counterforts of reinforced concrete at 6 or 7 feet centres, the face of the wall being strengthened in a very similar way to that of the floor slabs, with the armouring interlaced with that of the counterforts—the whole sustained on a horizontal slab projecting to form a proper toe.

Roofs.—Roofs on the Hennibique system are mostly flat, built similarly to the floors, with sufficient cross falls on their exposed surface to drain off the rain water. They are sometimes used as reservoirs and cooling tanks, the one at the Southampton Cold Storage Building having a depth of two feet of water over the greater part of its surface, equal to a load of about 123 lbs. per foot super. Domes, cupolas, and other forms of roofs are also constructed on this system.

Columns, &c.—Columns, piers, and pillars are generally moulded *in situ*, the bars being first formed in position and retained by wire ligatures or flat iron distance pieces (Fig. 32) dropped over their ends from the top, and arranged about 15 inches apart. These rods are connected either to the sub- or super-structures by overlapping, or are cut off a little below the upper tension bars of the beam (Fig. 29). These columns offer great resistance to oblique strains.

Lintels, sills, mullions, and other small framings are usually moulded on the works, and afterwards fixed in position, being connected to the surrounding work in a similar manner to the columns.

Cantilevers.—Fig. 34 is a section of one of the cantilevers built with an overhang of 11 feet 5 inches at the New Grain Warehouses, West Wharf, Plymouth, showing the disposition of the reinforcing bars and stirrups. These cantilevers were

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tested to carry a load of 4½ tons per lineal yard. At Messrs. Weaver's flour mill at Swansea, cantilevers supporting five storeys have been carried out over a railway siding, thus obviating what would have otherwise been a loss of valuable space. Some remarkable cantilevers have been constructed at Chanteney, Nantes, on the River Loire. They have an overhang of 24 feet 7 inches supporting a platform 27 feet wide, being anchored to the warehouse at the rere of the wharf, the warehouse thus practically supporting the quay itself. This quay was tested by rolling a truck loaded with 42 tons along its platform.

Foundations.—Foundations, rafts and mattresses are made similarly to the floors, due attention being paid to the calculations for the proportion of metal and concrete for the loads they will have to sustain. Where it is not convenient to float the building, and the nature of the ground will advantageously permit, piles can be used with highly satisfactory results. Fig. 35 shows a foundation block constructed of concrete, with a trellis of steel bars crossing at right angles, the lower bars being supported at their intersections by the stirrups taken up to a point just underneath the surface of the concrete. At the plane of intersection of the block and the pier or column a steel plate is inserted, the better to distribute the vertical pressure.

Cylinders.—Cylinders are made of varying length in a similar way to the piles hereafter described. Diaphragms are built in and fastened to the inside at intervals proportionate to the size and supporting power required. The principal advantage over an ordinary cylinder is the dispensation of the hearting, the whole weight being taken by the cylinders themselves. They are sunk in the usual manner, and can be often combined with advantage with piles for wharf and jetty construction.

Piles.—In its application to pile work this system has met

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with conspicuous success, and the ability of these piles to withstand the severe shocks and vibration during driving is eloquent testimony to the homogeneity of their constituent materials. They are generally cast in suitable moulds supported by frames, the moulds varying in shape to suit the size of the pile. The working face of these moulds is left open; a cast-iron shoe is then placed in position at the bottom of the mould, and attached by wrought-iron straps to the lower portion of the pile (Fig. 36), these straps being turned over inwardly at their extremities to grip the concrete. The steel rods are then carefully adjusted to the fiduciary line by gauges to within an inch or so of the casing, and kept in place by stirrups and distance pieces, about $\frac{3}{16}$ inch diameter, dropped over the rods from the top to different points marked on the edge of the moulds, varying from 2 inches at the bottom and top to 10 inches at the centre of the length of the pile, to keep the rods from spreading under vertical pressure. Concreting is then commenced—a bucketful at a time, which must be thoroughly well punned as soon as placed in the mould, and as the height of the pile increases the working face of the mould is closed by shutters from 4 to 6 inches deep, running in grooves formed in the sides of the permanent casing. When the pile is of great length these vertical frames are somewhat costly. It is, therefore, sometimes more economical and convenient to make the piles in horizontal moulds. This has been done under the author's supervision, with results that will compare most favourably with those made on the vertical system. After about 38 hours the concrete is sufficiently set for the moulds to be stripped, and the piles are then allowed to remain from 28 to 40 days to set preparatory to driving.

The reinforcement for deck piles (Fig. 36), which are generally square, are four steel rods; the amount of steel varying from 2½, but never exceeding 5, per cent. of their sectional

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area, this area being proportional to the super load the piles will have to sustain. Hereunder are the sizes of some of these piles used at Southampton, together with the percentage of the steel armature :—

Section	Reinforcement	Percentage
12″ × 12″	4 rods $1\frac{1}{2}$ inches diameter	5
14″ × 14″	,, $1\frac{1}{4}$,, ,,	$2\frac{1}{2}$
15″ × 15″	,, $1\frac{3}{8}$,, ,,	$2\frac{1}{2}$
16″ × 12″	,, $1\frac{5}{8}$,, ,,	$4\frac{1}{4}$

Piles have been made in lengths up to 60 feet, the above 15 inch piles being 51 feet long, weighing 5 tons each, and will sustain a safe load of 45 tons apiece.

The armature of the sheet piles consists of 6 rods instead of 4 where their breadth is much greater in proportion to their depth (Fig. 37). These piles are also fitted with a cylindrical groove on either side, extending from the top of the shoe to the upper end of the pile, and on its longer side at the lower end is fixed a metal spur fitting into the groove of the pile, preceding it to act as a guide in driving. When driven these grooves are carefully cleaned out with a water jet, and then filled with cement grout, thus forming a solid water-tight joint.

Where the nature of the strata will permit it with advantage, they can be driven with the water jet, and for this purpose a $\frac{3}{4}$-inch gas pipe is carried down the centre of the pile, terminating in a $\frac{3}{8}$-inch nozzle at the point of the shoe (Fig. 36). They can, however, be driven with an ordinary pile-driver or by a combination with the hydraulic jet; but the La Cour pile-driver, with its quick, successive blows, together with a heavy ram and short drops, gives the best results. At Southampton Old Extension Quay they are driven on the combined

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system through a stratum of gravel and hard sand to a depth of 22 feet, by a 30 cwt. ram, falling 6 feet. Owing to the presence of clay and fine gravel it was found impossible to sink with the water jet alone; but on this system, with a hydraulic working pressure of 300 lbs. per square inch, they were driven to the requisite depth in less than an hour. Piles 14 inches square have stood being driven with a 2-ton ram, having a 6 feet drop. During driving the head of the pile is encased in a steel helmet (Fig. 39) filled with sand or sawdust, a tight joint of hemp and clay being made between the lower part of the helmet and the pile to prevent the escape of these materials. A timber dolly is interposed in the usual way between the ram and the pile head.

The advantages of these piles are their freedom from vibration; no "teredo" need be feared, as with wooden piles; no oxidation, as with iron ones, and no expenses for maintenance. These characteristics make them especially suitable for foundations for piers, bridges, locks of docks, and other similar structures, saving the heavy cost of cylinders, and in the case of masonry piers, the necessary, but expensive, cofferdams and pumping. These piles can also be moulded hollow, and applied to foundations on rocky ground.

Example I.—A steel concrete bridge over the River Caudal, Mieres, Spain, designed by Señor Ribera, comprising two arches each 175.5 feet span, with a rise of 19.6 feet for the first span, and 22.3 feet for the second one. The abutments are of masonry, the pier in the centre being of reinforced concrete, the total width of the bridge being 26.24 feet. The flooring is carried on arches 1.31 feet in width, 1.64 feet thick at the crown, and 2.62 feet at their haunches. Compared with a similar bridge of hewn masonry, the approximate weight of the Hennibique structure is 326.6 tons against that of the stone bridge, which would have been 1,650 tons, the volumes of the two structures being as 1 : 525, and the

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prices per unit as 3 : 1. Therefore, not only is the concrete steel structure much lighter and more elegant in appearance, but a marked economy in cost is obtained. Further, the loads upon these abutments being far less, the masonry may be correspondingly much reduced. There were 4,000 cubic feet of concrete and 504 lbs. of steel per lineal foot of the bridge excepting the pier. From these calculations the average price would be per cubic foot of steel and concrete erected *in situ*, about 3s. 8d., equal to about £15 per lineal foot of the bridge. These figures are, however, only approximate, and it is interesting to compare this bridge with the one of similar construction over the River Vienne, at Chatellerault, France, which has a central span of 172 feet, rising 15 feet 8 inches, and two lateral ones each of 135 feet, rising 13 feet, the total width being 26 feet 3 inches. This bridge was calculated to carry a live load of two files of four-wheeled axled carts weighing 16 tons each, the footways simultaneously supporting a dead load of 100 lbs. per foot super. Its total cost was a little under £8,000, and length over all 442 feet, being equivalent to about £18 12s. per lineal foot of span. This in point of a single span makes the Mieres bridge the longest span yet carried out in armoured concrete.

Example II.—Another example of Hennibique construction is a quay wall in ferro-concrete. It consists of a front row of sheet piles, marked A, Fig. 46 (also see Fig. 37), divided into bays of 7 feet from centre to centre by a modified sheet pile, called a counter, driven with its shorter side in the same plane as the external face of the others; behind these, also at seven feet centres, are three rows of square or deck piles, B, Fig. 46 (see also Fig. 36), supporting and intimately connected to the beams and the superincumbent concrete steel platform or decking. Upon the sheet piling is fixed the superstructure or curtain (C) of the quay, stiffened at every 7 feet by reinforced concrete angle pieces or buttresses (D),

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these in their turn being built into the curtain at the side and the decking beneath, as far as the first row of deck piles, the whole being surmounted by an armoured concrete coping (E). Elm fenders (F) are attached to the face of the quay by iron bolts fixed through the sheet piling and curtain. On the face of the wall, at the junction of the sheet piles, curtain, and decking, is formed a continuous projecting waling (G), which not only gives additional horizontal strength, but adds to the finished appearance of the quay itself.

The size and armature of these piles is given hereunder :—

Pile	Size	Reinforcement		Percentage
Sheet	14″ × 8″	6 rods	$\frac{7}{8}$″ dia.	3
Counter	14″ × 8″	4 ,,	$1\frac{1}{8}$″ ,,	3
Deck	9″ × 9″	4 ,,	$1\frac{1}{8}$″ ,,	4
Special	12″ × 12″	4 ,,	$1\frac{1}{8}$″ ,,	2

The live load is practically carried on the decking, the buttresses bracing the curtain against the impact of vessels transmitting the pressure on to the decking, where it is distributed over a large area; while the fenders protect the face of the concrete from any damage likely to be caused by actual contact with the ships' hulls. In the calculations for this structure, the materials are assumed to be homogeneous, and treated as a retaining wall. It is instructive to compare the dimensions, mass, &c., of this steel-concrete wall with a masonry one for the same loads. The cost of this structure is estimated at £22 per lineal foot, being about half the cost of a masonry one.

Wayss System.—This system is not at all dissimilar to the Hennibique, only minus the stirrups, and in partition work the horizontal reinforcing rods are given a slight degree of

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upward curvature (Fig. 40). This distributes the load over a larger area of the reinforcement of the floor beneath, the horizontal rods being also carried to a certain extent into the floors, walls, and ceiling, so as to form a complete bond with the surrounding work.

Bonna System.—The object of M. Bonna is not only to produce a monolithic structure in concrete, but also to provide it with an entire ossature of metal. It is considerably used in France for buildings, tunnels, pipes, reservoirs, &c., and its difference from all other systems in its application to buildings arises from the fact that a complete metallic skeleton is first erected, and then afterwards enveloped in concrete. The reinforcement of an edifice in its entirety built according to this system is distinguished from an ordinary building only by the lightness of the framework, the few bolts, and the absence of braces and reinforcing plates. The purpose of these bolts is to sustain the framework until the concrete has become permanently set. Rolled steel sections (Fig. 41) of a cruciform shape are generally employed, ranging from about a $\frac{1}{4}'' \times \frac{1}{4}'' \times \frac{1}{24}''$, and about $1\frac{1}{2}'' \times \frac{5}{8}'' \times \frac{1}{8}''$, weighing from 0.075 to 1.125 lbs. per foot run, the moment of inertia being much greater than for round bars of the same sectional area. For heavy loading, sections as large as $1\frac{1}{4}'' \times 1\frac{1}{4}''$ to $1\frac{1}{2}'' \times 1\frac{1}{2}''$ are used. Sections of tubular form, made of 4 angle bars connected by plates, are the usual arrangement for beams, or by use of the cross-shaped sections they can be constructed of a sinusoidal form. These beams are of sufficient strength to support the principal loads, even before the embedding concrete is added, and the maximum shearing effects and bending moments are transferred to their extremities in such a way that the former are counteracted by the adjacent armature. These sections possess great rigidity apart from the support of the concrete, and it is evident that if rods of circular section were used it would be

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necessary to provide for the dislocation which would inevitably take place under the weight of the concrete itself before it became set and properly adhered to the metal. It can be readily perceived that this method of construction enables an advantageous application of the computations for resistance, together with a substantial economy of materials. In practice, the edge of the flanges of the metal framing are nicked at regular intervals, each bar thus being a measuring rod, permitting of the ready identification of each piece, and facilitating a rapid and accurate erection of the structure.

Pipes.—Longitudinal and spiral rods of the section just described are used for the reinforcement of pipes (Fig. 42) and circular reservoirs on this system, and an interior lining of thin steel is added for pipes subjected to great internal pressure, as in water mains. In this case the joints of the inner tube are made with short sleeves, packed in a similar way to that of an ordinary cast-iron pipe, and where long continuous lengths of pipe are being laid down it is requisite to have at frequent intervals an expansion joint made of a simple sleeve of sheet steel, with packing rings of rubber and asbestos, these being retained in position by the concrete. For water mains of very large diameter a double reinforcement may be employed with a lead-lined sheet-iron pipe inside, the connecting portions being made either by means of sheet-iron sleeves and concrete or by light cast-iron sockets. Branches are easily made to pipes of this kind, the external concrete and portion of the reinforcement being cut away, and the cast-iron branch and stop cock being attached by means of ring-bolts; the exterior joint is then made with a washer of leather, and the interior lead-lined pipe is finally cut through with a chisel. Extensive use has been made of these pipes in the large and important works of the water supply of the City of Paris.

Tunnel.—The construction of tunnels naturally intimately

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resembles that of the pipes, only that their section is generally elliptical or three-centred. In connection with the drainage works of the City of Paris, at Achères, a tunnel was constructed on this system, with a depressed arch, elliptical in section, with curved side walls and a flat-dished invert of the following dimensions :—16 feet 11 inches wide, 11 feet high, with a rise of 6 feet 7 inches. The skeleton is composed of a lattice of rods spaced 4½ inches apart, one set following the curve of the arch and side walls, being ⅝ inch diameter; the other, ¾ inch diameter, being longitudinal, these rods being united at their intersections by iron wire. The concrete of the arch is 3⅛ inches thick, the invert being formed of concrete *in toto*. When it was desired to render any portion of this structure water-tight, a thin sheet of lead was placed over the first layer of concrete, and held in position by light iron hoops, the full thickness of the concrete being then applied.

Melan System.—First applied in Austria, and afterwards introduced into the United States. In this system the reinforcement consists of beams of I section embedded in the concrete, and ligatures take the place of stirrups, as in the Hennibique System, to resist the shearing stresses in arches (Fig. 43). This method appears inferior to those in which the metal and the concrete have greater respective freedom in resisting the stresses, and there is also the seeming disadvantage in the absence of connecting members between the reinforcement. An example of this construction is the bridge over the Kaw River, Topeka, Arkansas. It is divided into five spans, the longest of which is 125 feet 3 inches, the span of the reinforcing skeleton being 138 feet 6 inches, this being also the distance from centre to centre of the piers. The rise is ⅕th of the span, the thickness of the arch being 8 feet 3 inches at the springings, and decreasing from thence to 1 foot 8 inches at a distance of 42 feet 6 inches from on each side of the centre. The width of this structure is nearly

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40 feet, the metallic reinforcement consisting of arched lattice girders, formed of 3″ × 3″ angle bars, with top and bottom chords 8″ wide. The cost of this bridge, including the approaches, was £28,800.

Bordenave System.—This system has a very close resemblance to that of Monier, with the exception that the reinforcing rods are of the I, U and L sections.

Roebling System.—The Roebling System of fire-resisting construction is extensively in vogue in the United States, where it is mainly employed for the floors of steel skeleton buildings. Its chief characteristic consists in the employment of arches of round rods and of wire network, the arches springing from steel joists to steel joists, and resting on their bottom flanges. Owing to the rise of these arches being less than the depth of the joists the whole space, including the spandrils, is filled with concrete up to the level of the top flanges, the reinforcing arches being thus wholly embedded in the concrete. This arrangement of the reinforcement is exceptionally strong, and when finished forms a solid monolithic mass.

Ransome System.—In this system square rods twisted slightly are used as the reinforcement (Fig. 44).

Thatcher System.—Flat steel bars with projecting rivet heads are adopted. Both these systems are in use in the United States, and a high chimney-shaft was erected over there on the Ransome System a short while ago. The twisting of the rods and the projecting rivet heads, both devised to prevent the slipping of the metal in the concrete, are unnecessary.

Hyatt System.—In the Hyatt System, square perforated bars are placed in the concrete, round rods being threaded through the perforations (Fig. 45).

Schulter System.—The lattice is similar to that of Monier, but arranged diagonally, the rods being of equal strength.

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Donath and Muller System.—In this system the transverse rods zig-zag between each pair of longitudinal ones.

Banks' System.—A network of helical lathing made of flat wire, with rounded edges, 3 B.W.G. wide and 21 B.W.G. thick, is introduced. The meshes are in squares of $1\frac{1}{2}$ inches or in a plaid pattern of $2\frac{1}{4}'' \times \frac{3}{4}''$ respectively. Each strand will take a strain of 700 lbs., the slabs being formed 9 feet square continuously over rolled steel joists of the usual section, the lathing being embedded in breeze concrete. A superload of $4\frac{1}{2}$ cwts. to the foot was applied to a slab of this size and description designed to take the ordinary load of $1\frac{1}{2}$ cwts., the result being a temporary deflection of $\frac{5}{32}$ of an inch in the centre, with no permanent set.

Wunsch System.—The distinguishing feature of this system is the reinforcement of inverted T shaped ⊥ irons that are employed.

Habrich System.—This system, with many others, utilises spirally twisted flat bars without cross rods.

With the mention of this system the author will cease, as a repetition of their distinctive peculiarities only tends to become tedious, especially having regard to the fact that only the Monier, the Expanded Metal, the Hennibique, the Cottancin, the Wayss, and, at the most, one or two of the others, have been introduced in this country; but, prior to drawing this paper (which he is afraid has already exceeded the usual limits) to a conclusion, it is proposed to call attention to a few advantages and disadvantages which are peculiar to these methods of construction.

Other Considerations.

Freedom from Vibration.—Apart from the advantages already pointed out as appertaining to concrete itself is the comparative freedom from vibration owing to the monolithic nature of the work. This immobility and solidarity is

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characteristic of all steel concrete work, and it is a consideration of the utmost importance in designing mills, factories, and other structures liable to excessive vibration set up by moving loads. Tests carried out in this direction have given most highly satisfactory results.

Durability.—Regarding this most important point, the lapse of time has hardly yet been sufficient to give an absolutely definite result, but the evidence so far has been leading to an entirely favourable conclusion in this respect. In 1886 some armoured concrete pipes were laid in Grenoble, and on being taken up in 1901 were found perfectly sound and able to stand their normal pressure of 80 feet head of water. The author himself has seen iron which has been found embedded in some of the concrete of the walls in the Portsmouth Dockyard for over 50 years beautifully clean and in an excellent state of preservation. In addition to the other advantages, there is no loss of available section due to riveting, as in ordinary girders, and buildings erected on these principles are found to be warm in winter and cool in summer. It is also claimed by the exponents of these constructions that in comparison with other building materials it shows a saving of between 15 and 20 per cent., and that about one-third the time is required for their erection compared to one constructed with steel stanchions and girders in the usual way. Mention should be made that, as a general rule, the necessary materials can be procured with the utmost facility, and the ease with which they can be transported, especially in hilly and mountainous countries, where the moving of girders and heavy sections is all but impossible. Experiments made in Austria, as to the action of explosives, first on ordinary concrete, and then on steel concrete, demonstrate the marked superiority of the latter over the former. The effect on concrete itself was to shatter it in every direction, whereas on the armoured concrete the damage was closely

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localised, the surrounding concrete being quite perfect, and exhibiting not the least appearance of disintegration. Further, the maintenance of armoured concrete work is practically nil.

Unfortunately it has its disadvantages. The resistance of the reinforced concrete is considerably dependent upon the proportion of cement, the character of the sand, the quantity of water, and the methods of mixing; and in order to avoid deformations it is advisable to increase the thickness beyond that usually adopted, and *pro rata* to augment the proportion of the reinforcement, thus diminishing the economy of the construction.

With reference to the labour employed upon works of this description—in spite of statements to the contrary—experience has shown that in order to obtain the best results a special kind of skill is demanded of the workman, which means a correspondingly greater expense.

Before concluding the author desires to acknowledge his indebtedness for much of his information to the undermentioned authorities, viz.:—

Professor W. Ritter's "Die Bauweise Hennibique," Schweizerische Bauzeitung, 1899.

Herr J. Rösshander's "Theory and Practice of Steel and Concrete Construction," Schweizerische Bauzeitung, 1900.

Mons. Paul Christophe's "Le Béton Armé et ses applications," 1902.

Mons. Marie Auguste Morel's "Le Ciment Armé et ses applications," 1902.

Major Winn's, R.E., "Notes on Steel Concrete Construction," 1903.

And various papers published in the Proceedings Inst. C. E., and other technical societies' journals, transactions, &c.

Also Mr. Arthur Vye-Parminter, Architect, of Paris, for a great deal of the information relating to the Cottancin System.

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And to his brother, Mr. F. V. Galbraith, A.M. Inst. C.E.I., for preparing the lantern slides illustrating the subject.

Finally, and in conclusion, it is of the utmost importance in the application of these constructions that the engineer should know his materials, and that his factor of safety should invariably be ample in all calculations relating to their design, taking into consideration our present circumscribed knowledge of the subject.

THE VICE-PRESIDENT said he was sure they were all very much interested in the paper. To most of them in Ireland it was almost fables, so to speak, of what had been done elsewhere. He had not seen very many examples in this country of these large reinforced concrete structures. They were peculiarly suited to experimental results, because he did not think any exact theoretical investigations could be made of their strengths.

A paper like the author's was very useful. They would be very pleased to hear any gentleman who could give them any further information on the subject.

MR. J. P. GRIFFITH said he thought they could not allow the paper to pass unnoticed, although he came down that night, after barely skimming through the paper, thinking it would be quite impossible to have the discussion, as the paper was so long. But the Council turned the tables on them by dividing the paper into two.

The subject was of extreme interest to him. He had not any experience in reinforced concrete. The paper itself, even its first part, was full of considerable notes of warning to those who were going to embark in it. They were told that there were over 200 systems in use. This was perfectly true. If they were in practice they would be infested with circulars of patent designs. But if they carefully considered the matter they would find the real true practice must be dealt with on

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purely mechanical principles. You cannot shut your eyes, simply bury your work, and take chance that everything will be all right.

There were some remarks he would like to make on the first part of the paper, and he hoped also to take part in the discussion on the second part.

With regard to what the author said about the treatment of concrete cement and so forth, it struck him that the author gave a rather broad hint against intemperate concrete work, which was rather a fad amongst distinguished engineers in the present day.

With regard to the distribution of materials, he thought they must face it from the purely mechanical principle of strength of materials.

He did not know if you could take any cognizance of the tensile strength of concrete in these concrete floors and buildings. Undoubtedly where they were dealing with compression they gained very greatly by this combination.

The French had been extremely successful in constructing arches with a very large span. Ribs of steel or cast-iron, as the case may be, are used, stiffened by the concrete, and prevented from deflecting. Under circumstances of that kind they arrived at very satisfactory results.

Although, as English Engineers, they had been very slow in adopting these systems, still, he thought, in the future it will be very largely adopted in this country.

In architectural work this system had taken the place of what might be called the lath and plaster work if nothing else. In these structures it gave great facility for plastering. It took the place of laths in ceilings with very satisfactory results.

The second part of the paper was very practical, and he believed the author had promised some diagrams which would be of great help to the members.

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MR. LILLY said the paper was a very interesting one, and connected together the different systems that had been used for concrete work.

The first part dealt with a theoretical discussion of the subject, and it was to the theoretical part he would like to draw their attention.

In considering the question of these structures their principal aim should be to proportion the metal and concrete so that the metal took up the tensile stresses and the concrete the compression stresses; in the case of cast-iron the ratio of the strength to compression and tension was approximately six to one.

With regard to the question of elasticity, it was very important that the steel bars should not be stressed beyond their elastic limit. It was absolutely essential that this should be taken into consideration. When they had metal bars embedded in the material they should make sure that they could take their load, and that the stress did not go beyond these limits. The problem then was to put the steel in the right position with regard to the concrete, so that the steel and concrete could be considered to act as a homogeneous body. From the systems described the whole idea was to incorporate the steel in the concrete so that they could treat the whole mass as a homogeneous substance. That meant it would be necessary to have the bars of metal fixed in some way, so that they would not slide, and this was done in some systems.

With regard to thermal co-efficients, he was not quite sure whether it was right to assume that concrete would expand as much as steel, but the author had so many means of making experiments he did not like to say otherwise. They were perfectly correct in the assumptions that had been made if the substance was considered to be homogeneous, but it was not so if the thermal co-efficients were not the same.

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The author had suggested a sieve of 5,800 meshes with a residue of ten per cent. He thought this was rather a big residue. Finely ground cement would be better.

The question of mixing concrete was a matter of experience. He did not like to say much about it, but he would say the question of the time elapsing after mixing the concrete was very important, and did not seem to have been dealt with sufficiently in the paper.

The question of the ratio of the tensile strength of concrete and the compressive strength was one of great interest to him, because he had read a paper on the strength of materials. In it he showed that the strengths to compression and to tension, were related to one another and to the shearing strength.

Assuming the ratio of the strengths of concrete to compression and tension as 10 to 1, from his calculations the shearing stress would be about $\frac{1}{3}$. That would work out about 30 instead of 20, as given in the paper. He thought this was more than likely to be about the safe ratio.

The question of concrete was largely affected by the various kinds of cement. If they had concrete in which they had a large amount of cement it is perfectly certain that the ratio of the tensile strength and the compressive would be about 7 to 1, not 10 to 1.

Of course, like Mr. Griffith, he believed many of these structures would come to them later on, but if they were not properly designed they might predict that they would be failures.

Mr. B. D. Wise said the paper was the most interesting one he had heard for some time. As far as he was personally concerned he knew very little about the subject. It was an entirely new subject.

There was no doubt in districts where it was hard to get stone and brick they would very likely be able to get material

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for the concrete, and this would be of great assistance to architects and engineers.

In arch bridge work, where they could not get other materials, arches made of this concrete material should be equally good if not stronger.

He thought it was a subject they should consider seriously. A good deal depended upon the class of materials which they were able to get.

In the barracks at Belfast the contractor had put in some very large concrete slabs across a passage, the largest he had seen used in the North of Ireland. They were very successful. He believed Tee-iron was used in their construction. The experts and architects in Belfast expressed great surprise when they were being made, but the slabs have given the greatest satisfaction.

He had been speaking lately to the contractor, who told him they were giving great satisfaction.

He believed it was a matter they should all take up seriously, and use these concretes where they could not lay their hands on other suitable materials.

Mr. J. H. Moore said he had not done anything in the Béton Armé System, but 20 years ago it occurred to him that it might be possible to construct bridges by using steel rails covered with concrete. He got a number of old bridge rails and put them about 3 in. apart with about 9 in. of concrete on them. He put planks underneath the rails. These bridges were now as good as the day they were put up.

The steel rails took the strain and the concrete the compression. This worked perfectly. Consequently, now, wherever he wanted to get a bridge over a railway he used steel beams and the concrete, say about 9 in. deep.

He had no doubt it would be quite possible to make bridges of reasonable spans in that way, without putting in any of this Béton Armé or other expensive material. But put in

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steel beams 9 or 10 in. deep 3 ft. apart with concrete 9 in. deep, and they would get bridges that would carry the traffic.

He was going to erect a bridge over the Boyne with a 20 foot span, and he would probably use the same methods as he had done before.

He saw in the second part of the paper that mention was made of a bridge which was constructed with a span of 130 ft., and which was only 6 in. at the crown, without iron girders.

He thought there must be some mistake in this.

Mr. Fortescue said in the beginning of the paper the author states that "ordinary concrete as a building material has many manifest advantages, being much stronger than brickwork, fire-resisting, frost damp and vermin proof, and when such concrete has been strengthened by the addition in a proper manner of an iron or steel armature, it can be readily understood that these advantages are at once considerably enhanced." Now, he had doubts about that, whether ordinary concrete was really stronger than good brickwork, whether it was more fire-resisting than brickwork, also the question of frost-damp, and he did not see where the vermin proof part of the question came in at all. "And when concrete was strengthened by the addition of an iron or steel armature," how this could affect the question of the strength, the fire-resisting part, the damp or vermin proof he could not see at all. He really thought the thing should be considered.

With regard to the question of compressional resistance, and the factor of safety for heavy moving loads, he considered that the author's factor of safety of 2 was sufficient for heavy moving shocks of machinery. He did not know what the Board of Works would say about that question in this country.

With regard to the question of vertical hangers counteracting the shearing stress, he thought these would have very little effect in the shearing stress in the ordinary sense of the

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word, as a vertical force. He thought they would want to have a considerable number of vertical rods.

With reference to the question of shearing stress force, suppose the case of an ordinary floor where they had a plain concrete beam supported between two iron joists, with loads at various intervals, single loads. If they had two vertical hangers on either side of that load, what good would these vertical hangers be? How did these vertical hangers prevent the shearing stress of concrete between them, unless there was some strength in the concrete itself?

He was seeking for information.

Mr. R. H. Leask said he had some experience of this concrete work. Over 20 years ago he put in a number of floors. He put in one floor, 150 ft. long and 40 ft. wide, without any expanding metal. He also put in several floors in Dublin and Belfast, and they had stood perfectly, notwithstanding that in some cases where there were gas engines they were subject to considerable vibration.

But with regard to using concrete Armé and expanding metal. He had used it in Dublin in a floor 63 ft. long by about 42 or 43 ft. wide. It was carried on girders about 8 ft. 6 in. centres. The concrete was about 5 inches thick, with two layers of expanding metal between. This floor could carry about 300 lb. per square foot.

He was engaged on some work of this kind, and got an estimate for pillars, girders, rails, &c., for a floor, and the amount was £1,800; and for the same work with pillars and beams for the Béton Armé System, the same firm undertook to do the work for £900, which was a great saving. From his experience he believed that concrete floors made under the Béton Armé System were the best.

He had also used the system in constructing a stores in Waterford with satisfactory results. There the length of the stores was about 200 ft. and 40 ft. wide, with pillars.

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Artificial manure was stored there, and it exerted an enormous destructive force on the brickwork, which was not at all suitable for the purpose.

In a stores in Dublin there were pillars 8 in. diameter and 1 in. thick, which carried division planks. The effect of the thrust on these pillars was to break several of them right across.

In Waterford he put in pillars 15 ft. apart, and had a concrete wall carried between these pillars, which had expanding metal on the outside, and the concrete to 7 in. thick. These served the purpose very well, and were much cheaper than brickwork could possibly be.

He had the greatest confidence in using expanding metal. There was only one thing with regard to it that would cause him any uneasiness, and that was with regard to expanding it properly when laying it on and seeing that it was perfectly flat. Do not cut each row of meshes to the full level. He thought the best way was to shear off the ends after they had been laid.

THE AUTHOR, in reply, said the first attempt to reinforce concrete was made by practical men long before the theoretical analyses of its properties were studied, most of the different formulæ, therefore, while they have a rational appearance, are empirical only. In this wise they are very useful and convenient to the busy engineer in acting as a quick and safe guide in estimating, and other preliminary work for the calculations of various reinforced concrete structures, such as beams, provided the limits of the range of their application is strictly adhered to. This is not meant in any way to depreciate their value, but to draw attention to the fact that all these assumptions regarding the elastic properties of concrete, and their correlating ratios, to that of the metal, their allowed unit stresses, &c., are but merely numerical constants to be applied to the assumed empirical

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formulæ. All the formulæ given in the paper have been sanctioned by experience in being constantly used by all the leading authorities, Continental and otherwise, of this increasingly important branch of the Engineering profession.

In reply to Mr. Griffith, it is only in dealing with floors entirely of concrete that the tensile resistance is of importance, the strength of the floor in this case being the measure of the opposition offered by the concrete to this force; but in calculating steel concrete members, it is customary to ignore the tensile resistance of the latter material, the tensile strains being taken by the steel. This is the general practice, both on the Continent and in America, and has the dual advantage that it simplifies the computations and is on the side of safety.

He was quite in accord with Mr. Lilly as to the ratio between the modulus of elasticity of the steel in tension and the concrete in compression being high. If it could be called a fault it was a good one, being well inside the limits of safety; it had besides received the sanction of all the authorities on the subject, and had been adopted as the ratio in the Building Codes of Hamburg, Berlin, Dresden, Frankfort, New York, Chicago, &c.

With regard to the adhesion between the metal and the concrete, for all practical purposes experience has demonstrated that it is amply sufficient, and the author has yet to hear of a case of failure of a reinforced concrete structure from lack of this property. For example, take a steel bar of ¼-inch section, and 12,800 lbs. per square inch as the tensile limit it is permitted to sustain, the resultant is 800 lbs. for the bar on a span of say 40 inches, we obtain in square inches an area of the same amount equalling 20 lbs. per square inch to correspond to the resistance of the steel to tension. This shows that almost without exception the various devices for the non-slipping of the armature are superfluous.

The most careful experiments by different authorities have shown that the thermal co-efficients of expansion and

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contraction are identical to the fifth decimal, being ·000006 for iron and steel, and about ·0000055 for concrete, they may therefore be taken as practically the same. Experience, however, has shown that, taken by the seasons, this expansion and contraction must be provided for in reinforced concrete structures on the lines indicated in the paper.

With reference to the fineness of the cement used, the grade given was that generally employed, but he was of the same opinion as Mr. Lilly, that the finer the cement, caeteris paribus, the better the results. It was now possible to obtain cement which, with a seive of 32,000 meshes per square inch, would not leave a residue in excess of 9%; and the results of some compression tests, made with 5 to 1 concrete of this cement, and a coarser cement which gave a residue of 4% on a seive of 5,800 meshes per square inch, showed that after twenty-one days the former gave 180 tons per square foot against the latter's 103 tons; after forty-two days 245 tons against 164; and after fifty-six days the former gave 252 tons per square foot, a result which would compare very favourably with granite.

All concrete should be put in place as quickly as possible after mixing.

On the question of the shearing resistance of concrete, the value quoted was that given by M. Christophe as the safe minimum for structures of a permanent nature, subject to heavy moving loads; but for structures of a temporary character, for steady and uniform loading, the maximum limit of 35 lbs. is given. It would, no doubt, interest Mr. Lilly to know that the results of what few researches that had been made by foreign investigators on this property of concrete had tended to confirm his theory of the ratio and general interrelation of the stresses and strains set up in isotropical materials as set forth in his excellent paper read before the Institution.

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Referring to the action and sufficiency of the stirrups and ligatures in taking up the shearing stresses, even in a beam of moderate span, there were a considerable number, and it was their action in preventing the premature entrance of cracks by withstanding the tensile stresses working in the direction of the tension curve that their vertical arrangement increased the supporting strength of the beam, but to what extent it had yet to be proved.

Replying to Mr. Moore's observations anent the road bridge at Wildegg, Switzerland, he hoped the following additional particulars might interest him. The arch was 10 inches thick at the haunches, with a rise of 11 feet. It was reinforced with two complete trellises similar to that described and illustrated on Fig. 7, buried in the concrete close to the extrados and intrados respectively. The abutments and head walls were entirely of concrete, and there were no girders of any kind in the structure. It is calculated to take the super load of 102 lbs. per square foot, and is the boldest example extant of bridge work on the Monier system. As such it is a conspicuous success, no outlay having yet been incurred in its maintenance, and it is much stronger now than the day it was first completed, some fourteen years ago.

He was extremely gratified at the very cordial reception they had given to Part I. of his paper, and at the very interesting discussion that had followed its reading.

DISCUSSION ON PART II.

THE PRESIDENT (Mr. R. Cochrane) said he was sure they were all greatly indebted to the author for all the trouble he had taken in preparing the very elaborate paper he had presented to them. The trouble was very great indeed in compiling and collecting together such a mass of very valuable information and statistics.

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There was another way in which the author deserved their commendation. He was a comparatively new Associate Member, and had followed the example of the English Institution in coming forward immediately after his election with a paper. This was a practice which would be very desirable for some of their Associate Members to follow.

The works which had been described by the author were not altogether unknown to him in a practical manner. It was very interesting to notice that some of the works had been carried out under his own personal supervision, therefore the paper partook of a practical character—a character which was so much to be desired in the papers brought before that Institute.

They would be glad to hear any remarks from members or visitors in the way of criticisms, and he hoped they would hear some interesting remarks.

Mr. Fortescue said there was just one point he would like to say something about, and that was with reference to the buildings where the perforated bricks were used, and as shown by the author on one of his slides. Where a large number of wires were standing vertically it seemed to him that there would be some considerable difficulty in laying these bricks. He was interested to know how the bricks were elevated to the top of the wires and then threaded down over these wires. It seemed to him that there was a good deal of trouble and expense attached to this method. He did not know whether their local bricklayers would be experienced enough to lay the bricks in this way.

Mr. J. Chaloner Smith said he would like to ask the author about the concrete piles. It seemed to him that in making these piles that they would have to use practically cement mortar; the amount of metalling or broken stone in the concrete would have to be very small; no lumps would

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pass through 2½ in. rings. It would have to be very fine or it could not be packed or punned round these reinforcing rods. This would make the amount of labour greater, and the actual value of the concrete would be very much increased.

He would like to know how the cost of these concrete piles worked out.

Timber piles could be worked in structures of this kind at about 7s. per cubic foot.

He thought piles as described by the author and laid as he suggested could not be done for anything like that.

The handling of these tremendous heavy piles would also require to have special strong tackling to lift them. It would be necessary to use great care in moving them

The cost of these things was a matter of importance.

Mr. Galbraith, in reply, said, with reference to the perforated bricks, the wiring of these seemed to him rather troublesome and slow, although M. Cottancin had informed him that as many as from 3 to 500 bricks per day per man could be laid on his method when accustomed to the work.

With regard to the cost of the piles, the concrete piles erected at Portsmouth worked out at 5s. per cubic foot.

Of course they had the labour connected with the moving, and it was great. But they were not a bit afraid to drop one of these piles, as that had often been done for experiment. They had all the resiliency of timber work. They bounced up just like timber, and the concrete hardly chips off at all unless it struck some sharp object.

As a rule, in estimating the cost of these structures with regard to pile work, with the Hennibique System, it was found that they frequently approximated closely with timber work.

In conclusion he desired to express his sincere gratification and appreciation of the very kind way in which his paper

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had been received. It had been a great pleasure to him to return to the land of his ancestors, and if what had been recorded by him has been the means of arousing a keen and lasting interest on the part of his fellow engineers in these advanced methods of construction he will feel that his object will have been attained.

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[*4th May*, 1904.]

Mr. Robert Cochrane, President, in the Chair.

The following Candidate was balloted for and duly elected :—

Francis George Hopkirk as Member.

The Weight of Plate Girders.

By W. E. Lilly, Member.

The problems involved in determining the weights of plate, lattice, or triangulated girders have hitherto proved so complex that, so far as the author is aware, no general formulæ have been given which admit of general use in practice.

In this paper an analysis is given which admits of easy application in determining these quantities, and from which some interesting deductions are given comparing the relative economy of different types of girders.

The application of the analysis to the case of a plate girder under concentrated and distributed loads will be first treated of, other types of girders and distributions of load being afterwards considered.

It will first be necessary to state the fundamental relations that obtain between the load, shearing force, and bending moment diagrams when applied to the case of a girder resting on two supports. Let a system of loads be placed, as shown by the load diagram of Fig. 1, on the span of the girder, then the shearing force at any section AA of the span is the algebraic sum of the forces—that is, to the loads and reactions to either side of the section, and by determining these values for a number of sections the shearing force diagram shown on the figure is obtained.

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Now all systems of loads are either concentrated or distributed. Let W_1 W_2 . . . W_n refer to the concentrated loads, and ω_1 ω_2 . . . ω_n to the distributed loads on the span, then the shearing force at any section is $F = \Sigma W + \int w dx$, or expressed in words, the ordinates of the shearing force

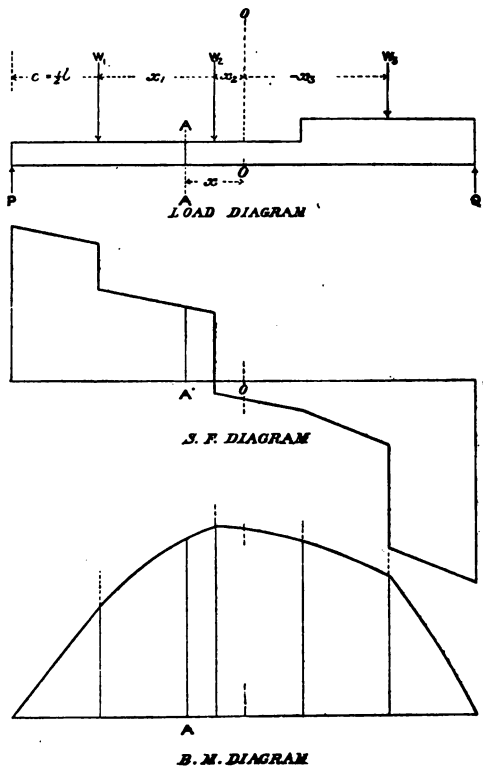

Fig. 1.

diagram are proportional to the algebraic summation of the concentrated loads, and one re-action, together with a load, proportional to the area of the diagram of the distributed loads to either side of the section.

The ordinates of the bending moment diagram are deter-

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mined by integration from the shearing force diagram—that is, $M = \int F\,dx = \Sigma Wx + \iint w dx^2$. From this equation it follows that the bending moment at any section is proportional to the area of the shearing force diagram measured from the ends of the span to that section. The bending moment will have its maximum value where the shearing force diagram cuts the base, the areas to either side of the point then being equal to one another—that is, the base line of the shearing force diagram divides the diagram into two equal areas. For girders supported at the end of this span, the relation is always true under all conditions of loading.

With rectangular girders the following relations will be shown to be true. That the theoretical volume of the web in plate girders, and of the struts and ties in lattice and triangulated girders is proportional to the area of the shearing

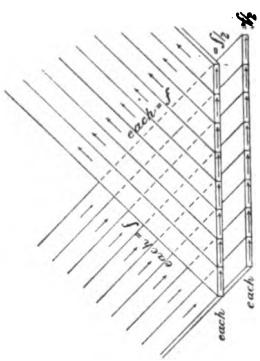

Fig. 2.

force diagram, and independent of the depth of the girder. This remarkable fact seems to have been first pointed out by Mr. Stoney, and greatly simplifies the analysis for the volume of such girders. The volume of the flanges, as is well known, is proportional to the area of the bending moment diagram, and varies inversely as the depth.

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In the analysis for the plate girder, the web will be assumed to be strained along lines inclined at 45° to the vertical, as shown on Fig. 2. As will appear from the investigation. there are good reasons for taking this angle. Further, from theoretical considerations, it can be shown that the lines of stress in a beam cut the neutral axis at 45°, and that for practical purposes this angle gives the nearest approximation to the direction of the lines of stress in the web.

On Fig. 2, the web is shown as being made up of two parts—one in tension and one in compression. It is convenient to do this, as it avoids some difficulties that would occur if the web were treated as being subjected to compound stress, and at the same time puts the analysis in the same form as will be required for lattice and triangulated girders.

Now consider a simple stress of intensity f acting through one of the bars, then on the vertical cut the shear stress would be $f \sin\theta \cos\theta$, and since $\theta=45$ the shear stress $s=f/_2$; also the normal stress would be $f \cos^2\theta$, giving again $f/_2$ when $\theta=45$.

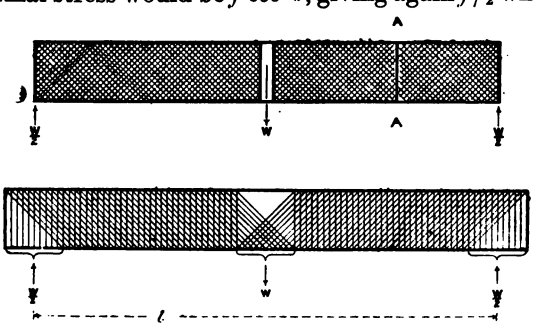

Fig. 3.

RECTANGULAR GIRDER 45° BRACING. CONCENTRATED LOAD.

On Fig. 3 a rectangular girder—that is, a girder with parallel flanges, with 45° bracing and vertical end struts—is shown carrying a concentrated load in the centre of the span. It is required to determine the theoretical volume of the girder.

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Volume of Flanges.

The bracing is inclined at 45°, and the shear stress assumed to be uniformly distributed over the web. Under these conditions the bending moments are wholly transmitted by the flanges.

The bending moment at the centre is $M = \frac{WL}{4}$; this is equal to $f\,a\,d$, where f = the working strength of the material, a = the area of the cross section, and d = the depth of the girder. Hence $a = \frac{WL}{4fd}$. The bending moments at the ends are nothing, and at any intermediate point vary directly as its distance from the ends of the span. Therefore the average area of the cross section of the flange will be one-half the maximum $= \frac{W\,L}{8\,f\,d}$; the volume for the two flanges will be the area of the cross section × 2-length—hence $V_0 = \frac{WL^2}{4fd}$. Let $\frac{d}{L} = r$, the ratio of the depth to span; then $V_0 = \frac{W\,L}{4\,f\,r}$

Volume of Web.

The shear stress over any vertical cross section is $\frac{W}{2}$; this equals $a_1\,f/_2$ where a is the area of the cross section of the web and $f/_2$ the intensity of the shear stress—hence, $a_1 = \frac{W}{f}$ and the volume is $a_1\,L = V_1 = \frac{W\,L}{f}$; that is, the volume of the web does not depend on the depth of the girder, and is constant.

The relation that the theoretical volume of the web is independent of the depth of the girder is true within wide limits. It is true for all conditions of loading, and applies equally to triangulated or lattice girders.

Volume of End Struts and Vertical Tie.

To distribute the load over the lattice bracing a vertical

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tie shown in the centre of the span is required. The area of its cross section at the lower flange would be $\frac{W}{f}$, and at the top flange would be nothing, giving an average of $\frac{W}{2f}$. The volume is the area $\times$ depth, equals $\frac{W\,d}{2\,f} = \frac{W\,L}{2\,f}\,r$.

The two end struts each carry a load of $\frac{W}{2}$, the area of the cross section on the lower flange being $\frac{W}{2\,f}$, and nothing at the top. Giving a mean area of cross section of $\frac{W}{4\,f}$ the volume for the two struts will be $\frac{W}{4\,f} \times 2\,d = \frac{W\,d}{2\,f} = \frac{W\,L}{2\,f}\,r$.

The volume for end struts and vertical tie then is $V_2 = \frac{WL}{f}\,r$.

Depth for Minimum Volume.

The total volume of the girder is $V = V_0 + V_1 + V_2 = \frac{WL}{f}\left(\frac{1}{4r} + 1 + r\right)$.

Differentiating the expression with respect to r the equation is $\frac{dv}{dr} = -\frac{1}{4r^2} + 1 = 0$ for the minimum value, giving $r = \frac{1}{2}$.

Substituting this value, the expression becomes $\frac{WL}{f}(\frac{1}{2} + 1 + \frac{1}{2})$, which shows that the volume of the flanges, end struts and vertical tie is equal to the web, also that the total volume $V = \frac{2WL}{f}$.

For *rectangular girders*, that is girders in which the internal system of triangulation admits of being indefinitely reduplicated, with the triangulation at 45°, the depth with the concentrated load that gives the minimum volume is invariably one-half the span. The result, however, is only of theoretical interest.

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Stiffening of Girders.

What is it, then, that fixes the economic depth of the girder? It is the material required to stiffen the web and flanges to enable them to transmit direct thrust, the allowance required for connecting the flanges together to transmit twisting moments, owing to the loads not being applied in the vertical plane of the girder, and the material required to allow for wind pressure.

It is impossible to neglect these quantities in any practical analysis on the volumes of girders, and, as will appear immediately, it is possible to introduce a co-efficient which will allow for them with a fair degree of accuracy.

RECTANGULAR GIRDER WITH 45° TIES AND VERTICAL STRUTS.

If instead of the bracing being at 45° the ties are supposed to be at 45°, and the struts vertical, as shown on Fig. 3, what then will be the volume of the girder?

Volume of Flanges.—The volume of these will be as before—$V_0 = \frac{WL}{4fr}$.

Volume of Web.—The volume of the ties will be as before $= \frac{WL}{f}$. In addition to this there is the volume of the vertical struts. The vertical component of the stress in inclined ties per unit of length along the flanges is $\frac{W}{2d}$, and the area of the cross section of the strut $= \frac{W}{2fd}$. The volume is the area of the cross section of the strut $\times Ld = \frac{WL}{2f}$. The total volume $V_1 = \frac{WL}{f}(1 + \frac{1}{2}) = \frac{3}{2}\frac{WL}{f}$. This includes the volume for the end struts in this case. The expression for the total volume is $V = V_0 + V_1 = \frac{WL}{f}\left(\frac{1}{4r} + \frac{3}{2}\right)$.

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As it stands, it does not give a finite value of r for the minimum value. A more rigorous analysis shows that the minimum again occurs when $r = \frac{1}{2}$, the volume of the flanges and struts being equal to that of the ties.

RECTANGULAR GIRDER 45° BRACING. UNIFORM LOAD.

Volume of Flanges.—The volume of the plate girder shown on Fig. 4 will now be determined—the load on the span being

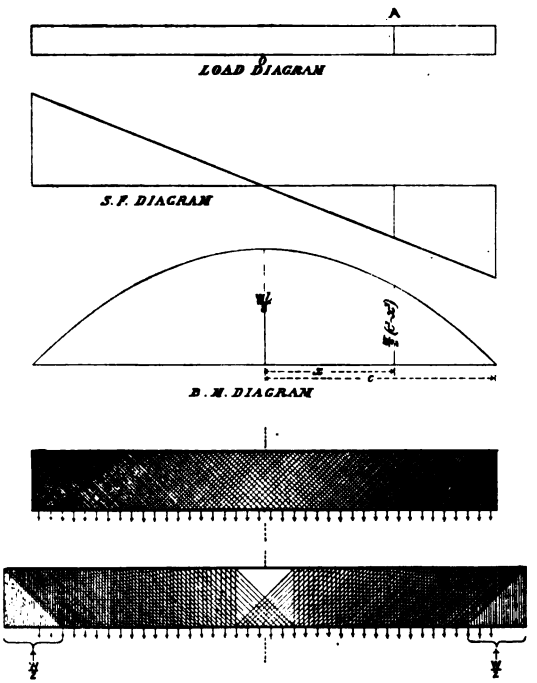

Fig. 4

uniformly distributed; the load, shearing force, and bending moment diagrams are given on the figure.

Let ω = the load in tons per foot on the span, L = the length of the span, and $c = \frac{L}{2}$. Take the origin of the co-ordinates at the centre of the span, then the moment

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M_x at any section is $\frac{w}{2}(c^2 - x^2)$. Suppose the flanges to take up the whole of the bending moments, then, since the depth $= d$ is constant, the cross section of the flanges will vary directly as the bending moment. Thus, let $f =$ the working stress of the material, $a =$ the area of the cross section of the flanges, then $f\,a\,d = M = \frac{\omega}{2}(c^2 - x^2)$ and $a = \frac{\omega}{2fd}(c^2 - x^2)$. The volume of any small element along the span is $\delta V = \frac{\omega}{2fd}(c^2 - x^2)\,\delta x$—hence the volume of the two flanges will be

$$V_0 = \frac{\omega}{fd}\int_{-c}^{c}(c^2 - x^2)\,dx = \frac{4}{3}\frac{\omega c^3}{fd} = \frac{WL^2}{6fd} = \frac{WL}{6fr},$$

where $r = \frac{d}{L}$ the ratio of the depth to span. The assumption that the flanges take up the whole of the bending moments is only true when the shear stress is supposed to be uniformly distributed over the web. A more rigid investigation given in Appendix 1 shows that a more accurate expression for the volume is $V_0 = \frac{WL}{6fr}(1 - r^2) = \frac{WL}{6fr}\left(1 - \frac{1}{4n^2}\right)$, where n = the number of turns to and fro of any one triangulation in the half span. To ensure no bending on the end struts the value of n should be some whole number. For the usual ratios of r in practice this effect is small, and may be neglected.

In the above equations $\frac{1}{2n} = r$.

Volume of the Web.—The shear stress over any cross section is proportional to the ordinate of the shearing force diagram of Fig. 4 at that section, and equal wx where w is the load in tons per foot on the girder. At the ends of the span this becomes $\frac{\omega L}{2} = \frac{W}{2}$, and gives the maximum value of the shear stress over the ends of the girder. The intensity of the shear stress is $f/_2$, hence the area of the cross section at the ends $= \frac{W}{f}\frac{2}{} = \frac{W}{f}$. The volume is the average area of the cross

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section $= \frac{W}{2f}$ multiplied by the length, $= \frac{WL}{2f}$—that is, the volume of the web is one-half of that for the concentrated load with the 45° bracing. It will be remembered that the areas of the shearing force diagrams for the concentrated load and the uniform load are in the proportion of two to one; hence it follows that the volumes of the web are proportional to the area of their respective shearing force diagrams.

Volume of End Struts.—The end struts transmit the shear stress from the bracing to the abutments, and the cross section of the strut will vary from nothing at the top to $\frac{W}{2f}$ at the bottom, giving a mean cross section of $\frac{W}{4f}$; the volume of the strut will be $\frac{Wd}{4f} = \frac{WL}{4f} r$, and for two struts the volume is $V_2 = \frac{WL}{2f} r$.

The vertical ties in this case are neglected, as the load can generally be transmitted to the bracing from the lower flange, and the ties are, therefore, not required. For the case where the depth is half the span, one-half of the load in the central part of the span must be supposed to be distributed on the central ties, and the case reduces to that of the concentrated load, thus:—

Total Volume.—$V = V_0 + V_1 + V_2 =$

$$= \frac{WL}{f}\left(\frac{1}{6r} - \frac{r}{6} + \tfrac{1}{2} + \frac{r}{2}\right).$$

The value of n cannot be < 1, which gives $r = \frac{1}{2}$ for the minimum volume. A more rigorous analysis allowing for the vertical ties gives the value of r very slightly under $\frac{1}{2}$. As before mentioned, these cases are only of theoretical interest; for values of $r \leqq \frac{1}{3}$, no difficulty arises with regard to the distribution of the load from the flanges, and no vertical ties are required.

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Rectangular Girder—Vertical Strut and Ties at 45°. Uniform Load.

On Fig. 4 a diagrammatic sketch of the girder is shown.

Volume of Flanges.—These will be the same as for the 45° bracing, and equal to $V_0 = \frac{WL}{6fr}(1-r^2) = \frac{WL}{6fr}\left(1-\frac{1}{n^2}\right)$.

It will be noted that n has twice the value of that for the 45° bracing.

Volume of Web and Struts.—For the inclined ties this is the same as that for the 45° bracing $= \frac{WL}{2f}$; for the vertical struts resolve the stresses in the inclined ties similarly as in

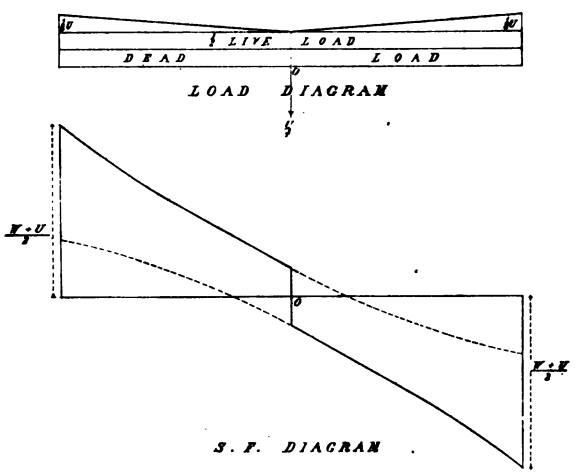

Fig. 5.

the case for the concentrated load; the value then obtained for the volume is $\frac{WL}{4f}$, giving a total volume $V_2 = \frac{3}{4}\frac{WL}{f}$. As in the case of the concentrated load, the volume of the end struts is included in this quantity.

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Live and Dead Loads.—In addition to the dead load on a girder it is necessary to take into account the live or moving load.

The shearing force diagram for the live and dead loads is shown on Fig. 5. It was proved by the author* that the distribution of statical loads shown on the load diagram of Fig. 5 would give the same shearing force diagram as would be obtained from the consideration of the moving and dead loads. If U is the total moving load, and W the total dead load, then the statical loads referred to are :—

A uniform dead load of $W+\frac{U}{2}$, a concentrated load of $\frac{U}{4}$ placed at the centre of the span, and a pair of wedge-shaped loads each of $\frac{U}{8}$, varying from nothing at the centre to a maximum at the ends of the span.

Now consider the application of these diagrams in determining the volume of the web for a plate girder, remembering that the volume of the web is proportional to the area of the shearing force diagram, the volumes for the concentrated, uniform, and wedge-shape loads are in the proportion of 1, $\frac{1}{2}$, $\frac{1}{3}$. This has been shown for the concentrated and uniform loads, and a similar demonstration applies for the wedge load. The following table gives these volumes in terms of the loads given on the load diagram :—

* Proceedings I.C.E. of Ireland, 1903.

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Volume of web $= \frac{L}{f} \times$

Loads	Ties and Struts inclined at 45°	Vertical Struts and Ties inclined 45°
Concentrated -	$\frac{U}{4}\left(1+\frac{r}{2}\right)^*$	$\frac{5}{8}U$
Uniform -	$\frac{1}{2}\left(W+\frac{U}{2}\right)\left(1+r\right)$	$\frac{3}{4}W+\frac{5}{8}U$
Wedge Shaped	$\frac{1}{3}\,\frac{U}{4}\left(1+\frac{3}{2}r\right)$	$\frac{1}{8}U$
Total Volume $=$	$\frac{L}{f}\times\left[\left(\frac{W}{2}+\frac{7}{12}U\right)+\frac{1}{2}(W+U)\,r\right]$	$\frac{L}{f}\times\left(\frac{3}{4}W+\frac{7}{8}U\right)$

The volume of the web is determined in terms of these co-efficients for the live and dead loads. The value of $\frac{r}{2}$ * has been taken instead of r for the concentrated load because no vertical tie is required, and only the end struts require to be considered.

Volume of Flanges.—The stresses in flanges will be a maximum when the live and dead loads are on the whole of the span, and the volume of the flanges for the 45° bracing and for the vertical struts and inclined ties will be $V_0 = \frac{(W+U)\,L}{6fr}\,(1-r^2)$.

Volume required for Stiffening the Girder.—If the theoretical volumes of the flanges and web were alone to be considered the economic depth would be given when $r = \frac{1}{2}$ nearly; this will be evident from the formulæ just given.

In determining the practical economic depth it is necessary to allow for the volume of material for stiffening the web as

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a strut, for stiffening the connections of the flanges together by gusset plates, to take up the twisting moments caused by the loads not acting in the vertical plane of the girder, for stiffening the gusset plates and struts to transmit wind pressure, and lastly, to allow for stiffening of the flanges considered as struts.

The allowance for these quantities will be made in two ways—firstly, by adding to the volume of the web and flanges a fixed percentage of their volume; and secondly, by adding a variable quantity, depending on the square of the depth.

Plate girders, in practice, are usually built with vertical struts, and approximate more nearly to the type of girder with vertical struts and inclined ties than to that with the 45° bracing. Using the co-efficients obtained for this type, the volume of the web is $\frac{L}{f}(\frac{3}{4}W + \frac{7}{8}U)$.

Now, to allow for butt-straps, joints of connections, the extra material (owing to the rivets reducing the efficiency of joints), and for the gusset plates, about 25 per cent. of the theoretical volume will be added to the web—that is, $\frac{L}{f}(\frac{1}{4}W + \frac{1}{8}U)$, giving for the total volume of the web $V_1 = (W+U)\frac{L}{f}$.

For the stiffening of the web as a strut, the Rankine Gordon Formula, Appendix (2), will be used in the following form:—

$A_1 = A_0 c\left(\frac{l}{\rho}\right)^2$ where A_1 is the area of the cross section to resist bending, A_0 the area of a short strut to carry the given load, $c = \frac{1}{9000}$, the co-efficient for round-ended struts, $\rho =$ the radius of gyration of the section, and $l =$ the length of the strut.

Now, consider the plate girder with vertical struts and inclined ties, the theoretical volume of the portion of the

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web which acts as a strut under a uniform load in this type is $\frac{WL}{4f}$; this is constant and independent of the depth. If A_0 is the cross section of the struts and d the depth of the girder, then $A_0\ d = \frac{WL}{4f}$, but $d = Lr$, therefore $A_0 = \frac{W}{4fr}$. substituting in the Rankine Gordon formula

$$A_1 = \frac{Wc}{4fr}\left(\frac{Lr}{\rho}\right)^2,$$

the volume for stiffening the struts is

$$A_1 d = A_1 Lr = \frac{WLc}{4f}\left(\frac{Lr}{\rho}\right)^2.$$

If V_1 is the volume for stiffening, and V_0 the theoretical volume for the struts $= \frac{WL}{4f}$, then

$$V_1 = V_0\, c\left(\frac{Lr}{\rho}\right)^2.$$

In a practical girder with $r = \frac{1}{10}$ the value of $\frac{d}{\rho} = \frac{Lr}{\rho}$ was from 65 to 70—that is, the mean breadth of the struts was about $\frac{1}{20}$ the depth; substituting these values $c\left(\frac{Lr}{\rho}\right)^2 = \cdot 5$, for any other depth the volume will be

$$V_1 = V_0 \times \cdot 5 \times 100\, r^2$$
$$= \frac{WL}{4f} \times 50r^2$$

and for the live and dead loads the volume is $\frac{W+U}{4} \cdot \frac{L}{f} \cdot 50r^2$; this gives the required volume; the value of ρ being assumed constant. With the bracing at 45° a similar investigation leads to an analogous result.

It is to be remembered that if the web were stiffened with this volume, so as to enable it to transmit direct thrust, yet the girder as a whole would be unstable; this will be evident by assuming the struts to have round ends. Hence, in addition to the above volume, there is still the volume required to

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stiffen the girder against wind pressure, and to withstand the twisting of the flanges to be considered.

The allowance for these can only be made empirically. In a particular girder of $\frac{1}{10}$ the span, the volume of material for stiffening struts, gusset-plates, &c., was sensibly $\frac{1}{2}$ the volume of the web. Now, for the struts, the volume required for stiffening varies as r^2, also for wind pressure the volume varies as r^2, and for stiffening against distortion by twisting the volume varies as r^2. Hence, for the particular girder of $\frac{1}{10}$ the span, the sum of these volumes added together would be $(W + U)\frac{L}{f} \times .5$, and for any other girder the sum of the volumes for struts, wind-pressure, and twisting could be put in the form $V_2 = (W + U)\frac{L}{f}(\cdot 5 \times 100)\, r^2$.

The theoretical volume of the flanges is $V_0 = \frac{(W+U)L}{6fr}(1-r^2)$. The practical volume is, however, greater than this, provision having to be made to enable the flanges to transmit thrust as a strut; also allowance must be made for the reduced section of the flanges, owing to rivets. Assume the value of $\frac{L}{\rho}$ to be constant, and not to depend on the depth of the girder, then the additional material required to stiffen the flanges as a strut will be a certain percentage of the volume of the flanges, and this will also be true for the rivets.

Further, the term $-r^2$ will also be neglected, as in all practical cases its value is too small to be of any consequence, and the increase of volume given by neglecting it would require to be allowed in other ways if it was retained.

To stiffen the flanges at least 20 per cent. requires to be added to the theoretical volume; if this is done the volume takes the form $V_0 = \frac{(W + U)}{5}\frac{L}{fr}$, this value will be adopted.

Formula for the Weight of Girders.—Collecting the terms

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for the volumes of the flanges, web, and for stiffening, the following formula is obtained :—

$$V = V_0 + V_1 + V_2 = (W + U)\frac{L}{f}\left(\frac{1}{5r} + 1 + 50r^2\right).$$

W and U being the dead and live loads on the span in tons, L the length in inches, and f the working strength of the material in tons per square inch.

This formula was obtained on the assumption that the ties were inclined at 45°, and the struts vertical; if, however, the bracing had been at 45°, the formula would have taken the form of $(W+U)\frac{L}{f}\left(\frac{1}{5r}+A+Br+Cr\right)$. A, B, and C being constants, a formula with these constants was determined, giving results which differed only in a small degree from the one already given.

If this formula is tabulated for various values of r it will be found that within a wide range of the depth the volume of the girder is sensibly constant, and that the minimum volume occurs when $r = \frac{1}{8}$, as will be seen at once by differentiating the above expression for values of $r = \frac{1}{7}, \frac{1}{8}, \frac{1}{9}, \frac{1}{10}$ the constant is sensibly 3.5. Adopting this value the formula takes the simplified form—

$$V = \frac{(W + U)\,L \times 3.5}{f}$$

and expressed in tons the weight of the girder for wrought iron is

$$W_1 = \frac{(W + U)\,L \times 3.5}{8000f} = \cdot 00043\,(W + U)\frac{L}{f}$$

This gives the weight of the girder to carry the dead and live loads. In addition to this there is the weight of the girder itself. The weight for this W_2 can be determined by simple proportion, thus :—

$$\frac{W_2}{W_1} = \frac{W_1}{W + U}$$

and the total weight of the girder is

$$W_{01} = W_2 + W_1 = W_1\left(\frac{W_1}{W + U} + 1\right).$$

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This formula has been tested against the actual weights of girders, and, as will be seen from the enclosed table, gives good average results. For spans below 40′ the values obtained require to be slightly increased. This is to be expected owing to the difficulty of designing small spans without a certain amount of waste of material.

WEIGHTS OF GIRDERS.

Total Length	Total Depth	Clear Span	Live Load Tons	Dead Load Tons	Total Load	Working Strength	Weight, Tons	Calculated Weight
38′ 0″	5′ 0″	33′ 0″	75	44	119	4.5	6	5.6
95′ 6″	10′ 6″	89′ 0″	164	106	270	4.5	31	33
45′ 6″	5′ 0″	40′ 6″	84	50	134	4.5	7.5	7.5
38′ 0″	5′ 0″	32′ 6″	72	35	107	4.5	5.3	5
111′ 0″	11′ 6″	103′ 0″	176	127	303	4.5	46	44
41′ 0″	5′ 0″	36′ 0″	78	41	119	4.5	6	6
38′ 0″	5′ 0″	33′ 0″	75	37	112	4.5	5	5.1
39′ 6″	5′ 0″	35′ 0″	75	41	116	4.5	6	5.6
100′ 0″	11′ 6″	94′ 0″	162	122	284	4.5	38	37
111′ 6″	11′ 6″	105′ 0″	177	138	315	4.5	46	47
106′ 0″	12′ 0″	100′ 0″	170	92	262	4.5	42	36.5

It is interesting to note that within wide limits the values of r do not cause much variation in the volume of the girder. This is in accordance with practical experience. Generally, for moderate spans, it is easier to design the girder with values of r from $\frac{1}{8}$ to $\frac{1}{10}$, the web then being thicker, and giving a girder with better proportions than could be obtained with greater depths, and the girder as a whole is easier stiffened. Considered theoretically, however, larger ratios could be taken with little or no greater volume of material in the girder.

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From the analysis it can be shown that if the volume of the web is imagined to be split up into two parts, one of which transmits the horizontal stresses, and the other the vertical stresses, then if the summation of the volume of the flanges and the part of the web transmitting the horizontal stresses is equal to that of the volume of the struts and that of the web transmitting the vertical stresses, maximum economy will be maintained.

This deduction from the analysis is perfectly general in its application to various types of girders, and has not hitherto been remarked. It may be more tersely expressed by saying that for economy the summation of the volumes for the horizontal stresses is equal to the summation of the volumes for the vertical stresses. The formula shows this when the value of r is about $\frac{1}{6}$ to $\frac{1}{8}$. It follows that if the economic depth is given by a certain value of r that it is always possible to design two girders, with a ratio of depth to span, one $\wedge\, r$ and one $< r$, having equal volumes, each of which may only be slightly in excess of the economic volumes. This explains the reason why so much discussion has taken place with regard to the economic depths of girders, the fact being that there is a range about the economic depth, in which there is little variation from the economic volume.

It is to be noted that whatever views may be taken with regard to the constants that have been adopted in the formula for the volume of the flanges, web, &c., any variation in these would not effect the general deductions alluded to, and would only affect the economic depths.

Generally speaking, it appears that in small spans the economic depth is small and increases as the span increases, varying from $r = \frac{1}{10}$ in small spans to as much as $r = \frac{1}{5}$ in large spans for lattice and triangulated girders.

To determine the moving load on a railway under bridge of any span the following formulæ, deduced by the author

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from Farr's Paper, *Trans. I.C.E.*, Vol. CXLI., are convenient:—

$$\left.\begin{array}{l}\text{The equivalent moving load}\\ \quad\text{in tons per foot}\end{array}\right\} = \frac{30}{\text{span in feet}} + 1.75$$

With the percentage allowed for impact by Mr. Farr the formula is :—

$$\left.\begin{array}{l}\text{The equivalent moving load}\\ \quad\text{in tons per foot}\end{array}\right\} = \frac{41}{\text{span in feet}} + 1.75$$

These formulæ show that the equivalent moving load depends upon a constant which is the equivalent moving load over a span of maximum length, together with a constant load divided by the span.

The whole question of the equivalent moving load can always be reduced to an equation of the form—$y = \frac{A}{x} + B$, the value of the constants A and B depending only on the rolling stock for any particular railway.

In conclusion, the author hopes in the near future to give the complete extension of the analysis to lattice and triangulated girders, and to show that the bracing at 45° is not only economically true for plate girders, but holds for all types of rectangular girders.

The author's thanks are due to Messrs. C. Draper and A. Neely for their kindly help in preparing drawings and revising the manuscript for this paper.

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APPENDIX.

(1) Volume of Booms.

Load uniformly distributed along the span, as in Fig. 3. Th· ties and struts are inclined at 45°. The shear stress $s = w \tan \theta$ and $\tan 45° = 1$, therefore $s = w$.

The area of the cross section of the flange at the centre of the span to carry this shear stress would be $a = \frac{w}{f}\frac{l}{2}$ and the volume v of $\frac{1}{2}$ one flange $= \frac{al}{2} = \frac{w}{f}\frac{l^2}{4} \times \frac{1}{2}$, the co-efficient $\frac{1}{2}$ being used because the average cross section is $\frac{1}{2}$ the maximum. Now, suppose the web to be developed and then to be doubled to and fro n times, and the load per unit of length along the span to be w per unit of length, then the summation of the volumes for one-half the upper and lower flanges would be of the form—

$$\frac{1}{2} V = \frac{w}{f}\left[\begin{array}{l} \left\{\frac{l\,n}{2n}\right\} \quad \left\{\frac{l}{2n}\,\frac{n}{2}\right\} \\ + 2\left\{\frac{l\,(n-1)}{2n}\right\} \quad \left\{\frac{2n}{l}\,\frac{(n-1)}{2} + \frac{l.1}{2n}\right\} \\ + 2\left\{\frac{l}{2n}\,\frac{n-2}{}\right\} \quad \left\{\frac{2n}{l}\,\frac{(n-2)}{} + \frac{l.2}{2n}\right\} \\ \qquad\qquad\qquad\qquad \text{etc.} \end{array}\right]$$

The summation of this series is

$$\frac{1}{2} V = \frac{w}{f}\left(\frac{l}{2n}\right)^2 \left[\frac{n^2}{2} + \left\{2\,(n-1)\left(\frac{n-1}{2} + 1\right)\right\} + \left\{2\,(n-2)\left(\frac{n-2}{2} + 2\right)\right\} \text{ etc.}\right]$$

$$= \frac{w}{f}\left(\frac{l}{2n}\right)^2 \left[\frac{n^2}{2} + (n^2 - 1^2) + (n^2 - 1^2) + \text{etc.}\right]$$

$$= \frac{w}{f}\left(\frac{l}{2n}\right)^2 \left[\frac{2}{3}n^3 - \frac{n}{6}\right]$$

$$= \frac{wl^2}{12f}\left[2n - \frac{1}{2n}\right]$$

And $V = \frac{wl^2}{6f}\left(2n - \frac{1}{2}n\right) = \frac{Wl}{6fr}\left(1 - \frac{1}{4n^2}\right)$

$$= \frac{wl^2}{6fr}\,(1 - r^2) = \frac{Wl}{6fr}\,(1 - r^2).$$

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(2) THE RANKINE GORDON FORMULA FOR STRUTS.

Let P = load on strut
A = area of cross section
f = working strength of material
$c = \frac{1}{9000}$ for round ends
l = length of column
ρ = radius of gyration

then

$$P = \frac{fA}{1 + c\left(\frac{l}{\rho}\right)^2}$$

Let $P = fA_1$ where A_1 is the cross section of a very short strut, then the formula can be put in the form—

$$A_2 = A - A_1 = A_1\, c\left(\frac{l}{\rho}\right)^2$$

where A_2 is the area required to be added to A_1 to prevent the strut bending.

THE PRESIDENT (Mr. Cochrane) said the paper contained some very original and valuable deductions. For instance, the author's statements about the rectangular girders were quite original; that is, that the theoretical volume of the web in plate girders and of the struts and ties in lattice and triangulated were proportional to the area of the shearing force diagram, and independent of the depth of the girder.

The formulæ which he gave them for stiffening the web struts were also of very great practical value.

The formulæ for the weight of the girders were, as far as he knew, quite original. He had not seen anything like that before.

He was sure they were all greatly indebted to the author for bringing forward this original paper; also for the very expert manner in which he had treated such very difficult mathematical formulæ.

He hoped some of their members would be able to speak on the subject. It was a very learned paper, but it was one that the ordinary practical engineer would shrink from

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discussing. He hoped that would not deter some of their members from offering their criticisms, and giving the author something to reply to.

Mr. William Ross said he would like to ask the author for a little further information.

First of all, in the table of weights of girders he gave the working strength as 4.5. Did he mean by that the working load in tons per square inch of section? The author did not say whether the girders were made of steel or iron. Of course in modern practice tables for steel were very much more useful than tables for iron. Possibly the author may have calculated for iron, and when revising the paper perhaps he would change the figures for steel, so as to make the table more useful. Further, he would suggest that when giving the formulæ for weights of girders he should put them in such a form that the members could copy the formulæ into their "Molesworth" for reference.

If he would give them a formula with the value of each letter at the top, so that it would not be necessary to refer back to see the value of the various signs, the formula would be very much more useful and handy for reference. At any time it would then be possible to use the formulæ with confidence.

He left to the younger engineers, who were fresher from the classes than he was, to make any criticisms on the details of the paper.

Mr. Lilly, in reply, said he had been told by some of the members that he had left his paper too late in the session. However, he was not very sorry that the paper had not been very much discussed, because it was one of those papers that took some months to compile, and could not very well be disposed of after an hour's reading. For that reason he had not expected to hear many remarks from the members. He had hoped, however, to hear that some of the members would

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have been pleased with the matter that had been brought forward in the paper.

It was a very peculiar thing that so many thousands of girders were made, and yet there was no generally recognised rules by which they could be designed.

If the depth of the girder was increased the volume of the boom decreased and struts increased. They then had girders of exceptional depth or out of proportion. If they made the girder very small in depth they got a very small quantity of material at the struts and ties, and a great deal of material near the booms. There should be something between these two. There must be a happy medium. He considered that this medium was arrived at by considering the volume of the booms equal to the volume of the web and struts. So far as he knew this was never enunciated in that particular form before. He knew that the approximate rule used in the designing of rolled girders was to proportion the volume of the cross section of one of the flanges equal to the cross section of the web.

Considered from his hypothesis, what was true of the plate girder was also true for the rolled girder. The volume of the flanges would again equal the volume of the web for economy.

He said the theoretical volume of the web was independent of the depth of the girders. If they came to design plate girders they would find on referring to the usual text-books that it was stated that they should take the shearing stress at so many tons per square inch. If the volume, and therefore the area, of the cross section was independent of depth it was perfect rubbish to use formulæ like that.

With regard to the remarks of Mr. Ross, the working str ngth of materials had been taken throughout the paper in tons per square inch.

With reference to the value of loads, he had given formulæ

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for these in the paper. For railway work they depended upon the engine and rolling stock of the particular railway under consideration, but with the formulæ he had given there should be no difficulty in calculating the sizes of the girders.

He would try to give a simpler form for railway girders, but it would be very hard to do so, as the moving load was such a varying quantity.

Correspondence on Mr. Lilly's Paper on "The Weight of Plate Girders."

Dr. Bindon Stoney considered the subject of the author's paper, though perhaps more simply treated elsewhere, one of importance to engineers, for in the constant hurry of office work it is often desirable to use quick though approximate methods for calculating the weights of girders. Perhaps the first idea that suggests itself is to make a skeleton diagram of stresses, in the manner described at page 141, Vol. XXX., of the Transactions, and by the aid of this stress diagram make a rough design of the finished girder from which the weights of the various parts may be estimated. Though this method gives fairly accurate results, it is generally too tedious for a first estimate, and the weights of riveted girders, say, from 80 to 200 feet in length and of ordinary proportions of length to depth, may be quickly estimated, owing to the circumstance that the flanges are generally equal in weight to each other, and that the web is very nearly equal in weight to one flange. Moreover, the quantity of material in the compression flange is nearly equal to its theoretic central section multiplied by its length; for, though in theory the sectional area of the flange should be reduced towards the ends in proportion to the stress, it so happens that the empirical allowances for covers of joints, rivet heads, packings, and

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waste (that is, the difference between the actual and the theoretic flange) is closely compensated for, by assuming that the flange carries its central section uniformly throughout its whole length. The second example taken from the author's table of weights of (presumably wrought-iron) girders, at page 276, will illustrate this method of calculation. From this table we get the following data :—

Length over all	= 95.5 feet
Clear span	= 89.0 feet
Total depth	= 10.5 feet
l=Length for calculating stress	= 92.25 feet*
d=Depth for calculating stress	= 10.2 feet

a=Sectional area (in square inches) at centre of either flange.

f=The working unit-stress = 4 tons per square inch of gross area.†

F=the total stress at centre of either flange.

W=total load = 270 tons uniformly distributed.

Using these data we have, from the well known formula for the central stress in either flange of girders supporting uniform loads,

$$F=\frac{Wl}{8d}=\frac{270\times 92.25}{8\times 10.2}=305 \text{ tons.}$$

Hence, the sectional area at centre of either flange,

$$a=\frac{F}{f}=\frac{305}{4}=76.25 \text{ square inches.}$$

* The length for calculating stress is measured between the centres of bearings on the abutments, and the depth for calculating stress in plate girders is usually measured between the root of the angle-iron connecting the web with the upper flange and the root of the corresponding angle-iron of the lower flange, and is therefore a little less than the total depth.

† Owing to the reduction of effective area by rivet holes in the tension flange, the usual working stress for the tension flange of wrought-iron girders—namely, 5 tons per square inch of *net* section—practically requires the same sectional area in the tension flange as the ordinary working stress of 4 tons per square inch of *gross* section requires in the compression flange.

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Recollecting that each flange is assumed to be of uniform section throughout its whole length and that 4.6 cubic feet of iron weigh one ton, we have the weight of one flange $=\frac{76.25 \times 95.5}{12 \times 12 \times 4.6}=11$ tons nearly.

The weight of the whole girder is three times this, or 33 tons, which agrees with the calculated weight in the author's table.

The late Sir William Anderson devised the following simple rule for estimating the weight of wrought-iron railway bridges under 200 feet in length, whose depth equals $\frac{1}{12}$th of their length, and whose working stresses are those sanctioned by the Board of Trade :—

Multiply the total distributed load in tons by 4, *and the product is the weight of the main girders, end pillars and cross-bracing, in lbs. per running foot.*

Applying Anderson's rule to the foregoing example we have $270 \times 4 = 1{,}080$ lbs. = the weight of the main girders, end pillars and cross-bracing per running foot; and their total weight $= \frac{1{,}080 \times 95.5}{2{,}240} = 46$ tons. Anderson's rule, it will be observed, gives a higher result than before, doubtless to a large degree because it is based on the depth being $\frac{1}{12}$th of the length, whereas in the author's example the depth is about $\frac{1}{9}$th of the length. Since, however, flange stress varies theoretically as the depth, we may multiply 46 tons by $\frac{9}{12}$, that is, by the ratio of the depths of the respective girders, and we get $34\frac{1}{2}$ tons for the weight of the deeper girder, which is but little in excess of the calculated weight in the author's table. Moreover, Anderson's rule includes cross-bracing, which the first method does not take into account.

The following table, calculated by Sir Benjamin Baker, gives the weights of wrought-iron plate girders up to 200 feet span, based on their depth being $\frac{1}{10}$th of their length and

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the working stress equal to 4.5 tons per square inch in tension :—

Weights of wrought-iron plate girders, the depth being $\frac{1}{10}$th of the length, and the working stress 4.5 tons per net square inch in tension—i.e., the section after deducting rivet holes.

LOAD IN CWT. PER FOOT RUN (EXCLUSIVE OF THE WEIGHT OF THE GIRDERS).											
Span in feet	10	15	20	25	30	35	40	50	60	70	80
	Weight of Girders in cwts.										
10	5.6	6.5	7.4	8.3	9.2	10.2	11.0	12.8	14.6	16.2	17.5
15	10.0	11.9	13.5	15.2	16.7	18.4	20.2	23.4	26.4	29.2	32.0
20	17.8	20.5	23.4	26.3	29.0	31.7	34.5	40.3	45.6	50.5	55.5
25	26.6	31.0	35.4	39.3	44.2	48.0	52.0	60.8	68.6	76.0	83.5
30	38	44	50	56	62	68	74	86	97	108	118
35	51	58	66	74	82	89	97	113	129	145	160
40	65	75	85	95	105	115	125	145	166	187	209
45	82	94	106	118	130	142	154	180	207	236	264
50	101	115	130	144	159	173	188	220	254	290	325
55	118	135	152	169	187	204	222	259	298	340	382
60	138	157	177	196	217	237	258	302	348	395	441
65	159	181	204	227	251	275	298	348	400	453	507
70	198	225	253	282	312	342	372	435	500	565	630
75	228	260	292	326	360	394	429	500	575	650	726
80	258	294	331	369	407	446	484	566	650	735	822
85	291	333	375	416	460	502	546	637	732	829	928
90	326	373	420	467	515	563	612	712	818	927	1040
95	365	417	470	523	576	630	686	800	920	1043	1172
100	406	464	522	581	641	701	764	892	1028	1167	1310
110	495	565	636	708	780	855	930	1090	1260	1430	1610
120	595	677	762	848	934	1020	1112	1305	1510	1720	1940
130	705	800	900	1000	1100	1200	1310	1540	1780	2000	2300
140	823	940	1059	1178	1298	1417	1546	1810	2085	2376	2686
150	950	1090	1230	1370	1510	1650	1800	2100	2410	2740	3100
160	1095	1255	1414	1574	1732	1896	2066	2415	2782	3172	3585
170	1250	1430	1610	1790	1970	2160	2350	2750	3180	3630	4100
180	1426	1626	1826	2036	2240	2450	2670	3140	3630	4130	4670
190	1614	1832	2060	2280	2510	2750	3010	3550	4100	4670	5270
200	1810	2050	2300	2250	2800	3070	3370	3980	4600	5230	5900

Taking the same example as before we have the load, exclusive of the weight of the girders $=270-31=239$ tons, and from this the load per foot run $=\frac{239\times20}{95.5}=50$ cwt.

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The clear span is 89 feet, and, taking something less than the weight given in the table for a 90 feet span, we estimate the weight of the girder at 695 cwt., or 34¾ tons, which is a little higher than the weight in the author's table. Again, taking another example—namely, that at the end of the table at page 276, the load, exclusive of the weight of the girders $=262-42=220$ tons, and from this the load per foot run $=\frac{220\times 20}{160}=41.5$ cwt. From the table we find the weight of the girders corresponding to a span of 100 feet $=783$ cwt. $=39$ tons, which is higher than the calculated, and lower than the actual weight, in the author's table.

It is interesting to observe that when their length exceeds 40 feet the ratio of the weights of *similar* girders having the *same load per running foot* vary in the foregoing table between the square and 2.3rd power of their lengths. Theoretically, the weights of similar girders, carrying the same load per running foot, vary nearly as the squares of their lengths.*

* Stoney on the Theory of Stresses, p. 234.

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Obituary Notice

OF

CHARLES PHILIP COTTON.

CHARLES PHILIP COTTON was born in Dublin on the 19th of January, 1832, and died at Bray, Co. Wicklow, on the 10th of March, 1904. His father was the Venerable Henry Cotton, Archdeacon of Cashel, and his mother, Mary Vaughan, younger daughter of Richard Laurence, Archbishop of Cashel. In 1848 he entered Trinity College, Dublin, and having obtained a Junior Moderatorship in Experimental and Natural Science he took out the degree of B.A. in the University of Dublin in 1853. In 1854 he received the Diploma of the Engineering School of that University, together with special certificates in practical engineering and in chemistry and geology. In January, 1855, he became a pupil of the late Mr. W. R. LeFanu, and subsequently acted under him as Resident Engineer during their construction of the Bagnalstown and Wexford Railway, the Mallow and Fermoy Railway, and the Roscrea and Nenagh Railway. In 1863 Mr. LeFanu was appointed one of the Commissioners of the Board of Public Works, Ireland, and Mr. Cotton, in conjunction with his partner, Mr. B. F. Flemyng, acted as Engineer-in-Chief, and finished the Railway from Wicklow to Wexford, the Roscrea and Nenagh Railway, and the Shillelagh Branch Railway.

From 1863 to 1867 Mr. Cotton was Engineer of the Port of Dublin Corporation, now known as the Commissioners of Irish Lights, and in 1879 he was appointed Chief Engineering Inspector of the Local Government Board, Ireland, which appointment he held till his retirement in 1899. In 1898 he was appointed a member of the Royal Commission on Sewage Disposal, and in 1900 he was appointed Chairman of the Viceregal Com-

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mission to inquire and report on the health of the City of Dublin. Mr. Cotton was the author of the following works:—A Manual of Railway Engineering in Ireland; A Manual of Procedure by Provisional Order under the Sanitary Acts; Loans Manual for the Use of Local Authorities; The Irish Public Health Acts, 1878–1890. He also contributed several papers to the "Transactions" of the Institution of Civil Engineers of Ireland. In 1861 he was elected member, and in 1873 President of the Institution. In 1861 he was elected an associate member, and in 1864 member, of the Institution of Civil Engineers. In 1878 Mr. Cotton married Marion Louisa, eldest daughter of Sir Maltby Crofton, of Longford House, Co. Sligo, and left no issue.

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REPORT OF THE COUNCIL FOR THE SESSION 1903–1904.

THE Council in presenting their Report on the work accomplished by the Institution during the Session for 1903–4 are pleased to be able to notice increased activity in all matters relating to its efficiency, and a continuance of its prosperity.

The roll has been added to during the Session by the election of 9 Members, 14 Associate Members, and 2 Associates. The numbers of Members, &c., at the close of the Session (allowing for deaths and resignations), as contrasted with the previous one, are as follow:—

		Members	Associate Members	Associates
1903–4	-	154	67	50
1902–3	-	150	54	54

The most important event to place on record is in connection with the visit to Ireland of their Majesties the King and Queen, in July, 1903, when your Council, through your President and Hon. Secretary, had the honour of presenting an Address from this Institution, which was most graciously received by their Majesties in person at the State Reception held in St. Patrick's Hall. The Address, with His Majesty's gracious reply, is printed at pp. 1 and 2.

On the invitation of your President and Council the Institution of Naval Architects visited Dublin on 25th, 26th and 27th June, 1903, and had most successful meetings and excursions. An influential Reception Committee was formed in April of that year, with your President (Mr. J. H. Ryan) as chairman, and two of your members (Mr. R. Cochrane,

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Vice-President, and Mr. G. M. Ross) as Honorary Secretaries. The Reception Committee entertained the members of the Institution of Naval Architects and the ladies of the party in the Rotunda, 25th June, where upwards of 500 sat down to luncheon. In the afternoon His Excellency The Earl of Dudley received the Visitors and Members of the Reception Committee at a Garden Party at the Viceregal Lodge, and in the evening The Right Hon. the Lord Mayor (T. C. Harrington, Esq., M.P.) gave a ball at the Mansion House in honour of the visitors. On the 26th June the business meetings of the Institution of Naval Architects were held in the Lecture Theatre of the Royal Dublin Society, and in the afternoon the London and North Western Railway Company placed their new steamer "Scotia" at the disposal of the Committee and their Guests for a trip in Dublin Bay. Saturday, the 27th June, was devoted to seeing the principal buildings in Dublin, with excursions to places of interest in the neighbourhood, and this completed a programme which gave much satisfaction to the visitors. The Council Room of your Institution was placed at the disposal of the Reception Committee and used by them for their meetings.

The visit of this Institution to Belfast in June, 1904, was a new departure, and one to which much interest was attached. Heretofore this Institution had not made any visit to works or arranged for excursions. It is worthy of a passing note that the Institution of Civil Engineers, London, also, for the first time in its history, undertook an excursion the same year.

On the 15th of June our Members travelled to Belfast and visited the Queen's Island Shipbuilding Works, and in the evening attended a reception given by the Lord Mayor in honour of the Members. On the 16th the Members, by invitation of the Harbour Commissioners, inspected the

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Harbour Works in the Commissioners' steamer "Musgrave," and afterwards visited places of interest in the city. In the evening they dined at the Grand Central Hotel, when some of the principal citizens were invited. On June 17th a visit was paid to the Works undertaken by the Northern Counties Committee of the Midland Railway at "The Gobbins," to make the beautiful cliff scenery of this portion of the Antrim coast more accessible. The party went on to Portrush for the night, returning to Belfast next day, and were under the guidance of Mr. Berkely D. Wise, *Vice-Pres.*, Chief Engineer of the Line, to whom is due the success of the meeting and excursion. A more detailed account of the meeting is given in the Appendix to this Report.

Owing to the decease of the trustees of the Mullin's Bequest it was found necessary to have a new trust deed prepared. This has been executed with the names of Wm. H. Mills, Robert Cochrane, John H. Ryan, and William Ross as trustees.

The accounts of the Institution have been audited by Messrs. Craig, Gardner & Co., and with their report are presented herewith.

The following are the Papers read before Institution, Session 1903–4:—

4th November, 1903.—"Some Remarks on Examinations, Competitive and Qualifying, as Avenues of Employment for Engineers." By Robert Cochrane, I.S.O., Vice-President.

2nd December, 1903.—"Some Simple Forms of Geodetical Instruments for Rapid Survey Work." By Sir Howard Grubb, F.R.S., Hon. Member.

6th January, 1904.—"Modern Foundry Practice." By E. C. H. Walker.

3rd February, 1904.—"Further Notes on Sea Coast Erosion." By R. G. Allanson-Winn, Member.

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2nd March, 1904.—"Iron, Steel, and Concrete Construction (Le Béton Armé)," Part I. By A. R. Galbraith, Assoc. M.

6th April, 1904.—"Iron, Steel, and Concrete Construction (Le Béton Armé)," Part II. By A. R. Galbraith, Assoc. M.

4th May, 1904.—"The Weight of Plate Girders." By W. E. Lilly, Member.

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APPENDIX

TO

REPORT OF COUNCIL FOR THE SESSION, 1903–4.

Belfast Excursion, June, 1904.

THE visit of the Institution to Belfast was looked forward to with great interest, not only by the members taking part in it, but also by a large section of the Belfast public, who gladly welcomed the representatives of the governing body of the profession in Ireland to their city, for the purpose of paying a visit to the leading engineering works in the North of Ireland. The expectation of a pleasant and successful meeting was fully realised, and a desire was expressed by many of the leading men in the city that the visit should be repeated soon.

On the 15th of June the party travelled to Belfast, the President, of the Institution, Mr. Robert Cochrane, I.S.O., having arrived the previous day at the Grand Central Hotel, which was the headquarters of the party during their stay. After luncheon the extensive Shipbuilding Works of Messrs. Harland & Wolfe were visited, and the new Graving Dock, which is being constructed by the Harbour Commissioners, was seen; the Assistant Engineer, Mr. W. Redfern Kiely, M.Inst.C.E., courteously conducted the members to the various points of interest, and exhibited the drawings prepared for the execution of the work.

In the evening the Lord Mayor of Belfast (Sir Otto Jaffe, J.P.) and Lady Jaffe gave a reception in the Public Library to the members of the Institution. The guests invited to meet them included the members of the Council of the City of Belfast and the representatives of the other public boards, together with a large number of local gentlemen connected with the engineering profession, and other distinguished persons.

Over two hundred persons accepted the hospitable invitations to be present, and a very pleasant evening was spent.

The Library and Museum, which were thrown open, were handsomely decorated, and the Art Gallery, which contains many interesting works, was inspected with much pleasure by the guests, and, in addition to the other exhibits, models were on view of the new Graving Dock under construction at a cost of

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£300,000, and of Whitehead Railway Station, planned by Mr. B. D. Wise for the Northern Committee of the Midland Railway Company.

On the 16th June the members enjoyed a trip down the Lough on board the steam tug "Musgrave," which was kindly placed at their disposal by the Harbour Commissioners, and they were afforded an opportunity of inspecting the works in connection with the new Musgrave Channel and the new Graving Dock, in both of which they were naturally interested. On returning they examined a new oil road roller, which had been brought down to the quays for the purpose, and then visited the new City Hall, where, through the courtesy of the contractors, Messrs. H. & J. Martin, Ltd., they were shown over the fine building now in course of erection. The party were photographed here by Mr. J. Phillips. In the afternoon a visit was paid to the Sirocco Engineering Works, on the invitation of Messrs. Davidson & Co., Ltd., where, after a minute inspection of the works and the different processes of manufacture, they were hospitably entertained by the firm.

In the evening the members of the Institution dined together in the Grand Central Hotel. The President, Mr. Robert Cochrane, I.S.O., occupied the chair, and amongst the visiters present and invited were—the Lord Mayor (Sir Otto Jaffe, J.P.), the High Sheriff (Mr. Henry Hutton, J.P.), Sir James H. Haslett, M.P.; Sir James Henderson, D.L.; the Right Honourable W. J. Pirrie, D.L.; the Right Honourable Thomas Sinclair, D.L.; Rev. Dr. Hamilton (President of the Queen's College), Messrs. W. J. Fennell, J. C. Bretland, Robert Young, J.P.; John Mackenzie, J.P.; Vincent Craig, F. C. Forth (principal of the Municipal Technical Institute), S. Stevenson, Hector F. Gullan, W. Redfern Kelly, J. H. Swiney, Bowman Malcolm, James Munce, and C. L. Boddie, S. C. Davidson, A. M. Carlisle, G. P. Culverwell, and others. Grace was said and thanks returned by Rev. Dr. Hamilton.

After dinner the loyal toasts of "The King" and "The Queen, the Prince and Princess of Wales, and the rest of the Royal Family," were proposed by the President, and were drunk with enthusiasm.

The Rev. Dr. Hamilton proposed "The Institution of Civil Engineers of Ireland," coupled with the name of the President. He said he could not pretend to speak in any way as an expert upon engineering matters or to use engineering parlance, but it appeared to him that in these days it required no expert—no one *au fait* in actual engineering affairs—to speak in the highest terms of the great profession to which most of those present

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belonged. In these days, when immense engineering works all over the world had been undertaken and carried to success by members of their profession—when, especially within the British Empire, where tracts of country, which used to be given over to sterility and desolation, had been reclaimed and handed over to the gentle sway of commerce, manufacture, and trade—he thought the engineer had proved himself to be one of the most potent pioneers of their modern civilisation. Nor, indeed, did they need to go beyond their own land for proof of the utility of the profession. No country in the world, owing to its peculiar conformation and the character of its inhabitants, needed the aid of the engineer more to develop its resources than Ireland, and they lived in a day when, by means of engineering feats, the country had been developed, and, he hoped, would continue to be developed, in a way which to their forefathers would have seemed perfectly marvellous. The North of Ireland had visible proofs of what engineering could do. He saw his friend, Mr. Wise, present that night, and he ventured to say that on the following day, when, under his guidance, they took their way along the line of railway of which he was the distinguished engineer, they would see feats of engineering—some on a small scale, and some on a larger scale—which would convince them that in the matter of engineering the North of Ireland was not altogether barren ground. Their Institution was an important one, and it occupied a place of great moment in this country. He was glad to find that amongst their members they had a larger number of university graduates than the corresponding institution in England. Possibly that very creditable fact arose from the circumstance that in Ireland it was easier to obtain a degree in engineering than in either of the two sister countries. It was something for their poor island to boast of that it provided four university colleges which trained men for the degrees of Bachelor of Engineering and Master of Engineering. That statement had to be qualified by the further statement that the equipment in some of those colleges at all events was far from being of the kind which it ought to be. They had an engineering department in the Queen's College, Belfast, and it might interest some of them to know that it was intended to erect, at considerable cost, a suite of laboratories in engineering and in physics, which they hoped would shortly be commenced, and which he expected would prove to be better by far in every way than anything of the kind with which any part of Ireland had hitherto been provided. He expressed the hope that they would come back when that suite was provided, and perhaps give them their presence at its opening. He was glad that that toast was

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coupled with the name of his friend, their President, for Queen's College was indebted to Mr. Cochrane, in his professional capacity and as a representative of the Board of Works, for the pure taste, architectural skill, and zeal in the public service he had displayed. He might mention, in conclusion, that their Institution gave to Belfast a Mayor and a Member of Parliament in the person of the late Sir Charles Lanyon, their first Secretary, the architect to whom, as County Surveyor of Antrim when the Queen's College was built, they owed the beautiful main building, which was the admiration of everyone who visited that part of the city.

The toast was duly honoured.

The President (Mr. Cochrane), in responding, after thanking Dr. Hamilton for the kind manner in which he proposed the toast, said :—The Institution is now in the 70th year of its existence, and, though its members have during that time been busily engaged in inventing and developing the means and facilities for travelling over the country, the Institution itself has not, until the present year, ventured to leave its head-quarters or to take advantage of the facilities which its individual members have been providing for others.

The Institution of Civil Engineers of Ireland, founded on the lines of the great English Institution, was, like the profession itself, brought into existence by the exigencies of the age. These Institutions are the governing bodies of professional practice in both countries, and are as necessary, indeed more necessary, to-day than at the time of their foundation. The primary object was to raise the standard of education of practising engineers, and it was with this object that the members of the Irish Institution took the initiative to have the Schools of Engineering in Trinity College and the Queen's Colleges formed. The Universities to which these schools belonged were afterwards enabled to grant degrees in engineering, and it is worthy of notice that engineering degrees are not known in the English and Scotch Universities, and only in Ireland are such obtainable. It is not to be understood, however, that equal if not better facilities do not exist in England and Scotland for the education of the engineer.

The practice in the English system is that when a young man has completed his scientific education, either at the University or one of the numerous Colleges of Science, he becomes, almost automatically, a pupil of an engineer in practice, as the necessary complement of his college course, and to learn the business portion of his profession.

In Ireland when a young man takes a degree in engineering, he is frequently disappointed to find that he cannot at once obtain remunerative employment, or even admission to the

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Institution, except in the Student Class. He must first qualify in practical engineering in an engineer's office. The number of those who have degrees in engineering are barely one-fourth of the duly qualified engineers in Ireland. Our Institution provides for the enrolment of qualified practitioners, and our lists of members are already made use of largely by the local bodies to see if applicants for employment belong to our Institution. There are unfortunately men who propose to do the work of a civil engineer who are not fitted by training or experience. This is sought to be remedied by compulsory registration. The question is not altogether a professional one, it is one of interest for the public also, as when a man calls himself a civil engineer the employer ought to be able to ascertain whether he is properly qualified or not.

In England the Institution of Civil Engineers has an income of about £20,000, it is one of the most important of the professional corporations of the Kingdom. Its members have not as yet considered it necessary to invoke the interference of the law; but Ireland is differently situated, and this Institution would gladly welcome any legislation which would make the registration of qualified engineers compulsory.

He mentioned the pleasure it gave him to meet again some of his former fellow-students of Queen's College, and especially at having as their guest that evening the revered and honoured President of that most valuable Institution, which reflects so much credit on the city of Belfast, and which had been the means of imparting engineering knowledge to so many of their profession whose lines are cast not only in this country, but are practising in almost every portion of the world.

Mr. B. D. Wise, in proposing the health of the Guests, said they were pleased to have with them some of the foremost scientific and professional men of Ireland. It gave them pleasure also to have amongst them several of their architectural brethren, for engineers and architects were pretty much in the same profession, and were alike trying to do what they could for humanity.

Mr. Forth, in responding, alluded to the success which was attending the technical education movement in Belfast, and said that those in charge of it hoped to have an engineering department when the new Technical Institute was completed. They trusted that the work done jointly by Queen's College and the municipality working in the most harmonious relationship would enable young engineers to secure at home all those privileges and advantages which had not been available in Ireland. Messrs. W. Redfern Kelly and J. H. Swiney also responded.

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Mr. W. J. Fennell proposed the health of the Vice-President, Mr. Wise, alluding to the good architectural work he had done in connection with the new stations on the Northern Counties Line. He agreed fully with the President on the subject of compulsory registration, and said that the Institute of British Architects was engaged in promoting such a scheme, and he thought the two Institutions should mutually assist each other in advancing such a desirable object.

The sentiment was cordially received, and was appropriately acknowledged by Mr. Wise, who expressed the pleasure it gave him to see the members of the Institution in Belfast for the first time. He also expressed the hope that there would be a closer union between the members of the twin professions of architect and civil engineer.

Professor Lilly proposed the health of the President, which was received with great cordiality and suitably acknowledged by Mr. Cochrane, who afterwards proposed "The Press," which was duly responded to.

During the evening a musical programme was rendered by the members of the Northern Quartette.

On Friday the members visited Ballycarry and the Gobbins in order to enjoy the walk along the cliffs, which had been formed by the Railway Company to enable the cliff scenery of this portion of the County Antrim sea coast to be made accessible from land. Tunnels were formed through rocks, and chasms were bridged over in a very skilful manner. In the evening the party proceeded to Portrush.

At the conclusion of the excursion the President proposed a vote of thanks to Mr. Berkeley D. Wise for the trouble he had taken in carrying out all the details of the visit to Belfast, which had been most successful in every respect, and afforded the greatest pleasure to the visitors. This was seconded by Mr. Dillon, Past President, and carried by acclamation.

On Saturday, the 18th, the Giant's Causeway was visited, travelling over the Electric Railway—the first of its kind in Ireland—returning to Belfast in time to enable those from the South to catch the 5 30 p.m. train for Dublin.

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AUDITORS' REPORT.

TRINITY CHAMBERS, 40 & 41 DAME-STREET,

DUBLIN, 11*th February*, 1904.

COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND, DAWSON-STREET, DUBLIN.

GENTLEMEN,—

We enclose for your information copy of the Revenue Account for the year 1903 and copy Balance Sheet to said date, prepared by us from the books and documents kept at your offices.

The expenditure for the year exceeded the income by the sum of £8 16s. 3d., but this is better than the preceding year, when the income was short £95 17s. 8d. to meet the outgoings.

The Cash Book has been well and carefully kept, and we have satisfied ourselves by an inspection of the vouchers and by checking the blocks of the receipts given for income of the accuracy of the cash account.

No record is kept on the books of the liabilities outstanding at any given date, and there might arise at any time a difficulty in tracing the various items due and comprising the liabilities of £182 1s. 2d. We would recommend that as these liabilities accrue there should be an account opened for them, so that at any time by turning up the books the details of the existing liabilities might be easily seen.

Yours faithfully,

CRAIG, GARDNER & CO.

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THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

BALANCE SHEET, 31*st December*, 1903.

LIABILITIES.		£ s. d.
By Sundry Creditors—		
Accrued Rent	£22 15 0	
Repairs and Taxes . . .	16 14 4	
Printing and Stationery . .	117 1 2	
Books for Library . . .	20 10 9	
Expenses General Meeting .	3 19 8	
Painting	1 0 3	182 1 2
„ Surplus to the credit of the Institution on 31st December, 1903, exclusive of the value of premises, library, furniture, and fittings as per last account,	1,607 3 10	
Less debit balance of Revenue Account, 1903 . . .	8 16 3	1,598 7 7
Total £		1,780 8 9

ASSETS.		£ s. d.
To Subscriptions in arrear 31st Dec., '03	£36 15 0	
Less paid in advance . .	11 11 0	25 4 0
„ The Mullen Bequest, £1,172 8s. 3d., 2½ per cent. Consols		1,172 8 3
„ Smith Testimonial Fund, £97 14s. 7d., 3½ per cent. India Stock		97 14 7
„ India 3 per cent. Stock, £135 4s. 6d. . .		149 15 3
„ Rents receivable due		130 10 0
„ Dividends on Investments due		8 17 1
„ Rates in advance		10 5 0
„ Cash in Bank		185 14 7
„ Premises, 35 Dawson-street, Dublin, under lease for 200 years from 1892, subject to annual rent of £105 and rates		—
„ Library		—
„ Furniture and fittings . .		—
Total, £		1,780 8 9

We have examined the foregoing Revenue Account and Balance Sheet, compared same with the Books and Vouchers of the Institution, and found them to agree. We have obtained certificates from the Bank of Ireland for the Stock.

DUBLIN, 11*th February*, 1904.

CRAIG, GARDNER & CO., *Auditors.*

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LIST OF MEMBERS.

INSTITUTION

OF

CIVIL ENGINEERS OF IRELAND,

Established 1835 (Incorporated by Royal Charter, 1877),

35 DAWSON-STREET, DUBLIN.

1904.

COUNCIL.

President:

ROBERT COCHRANE.

Vice-Presidents:

WILLIAM ROSS (*Hon. Treas.*) | BERKELEY D. WISE.

Other Members:

WM. ANDERSON,
FRED. J. DICK,
SAMUEL GEOGHEGAN,
JOSEPH H. MOORE,
GEORGE M. ROSS,
MARK RUDDLE,
PROSSER A. H. SHAW,
RICHD. O'BRIEN SMYTH.

Past Presidents:

(*Ex-Officio Members of Council*).

BINDON B. STONEY,
ALEX. M'DONNELL,
WILLIAM H. MILLS,
JOHN A. F. ASPINALL,
JOHN P. GRIFFITH,
SPENCER HARTY,
THOMAS F. PIGOT,
JAMES DILLON,
EDWARD GLOVER.
JOHN H. RYAN.

Honorary Secretary:

MARMADUKE BACKHOUSE.

Bankers:

ROYAL BANK.

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HONORARY MEMBERS.

(*Hon. M.Inst.C.E.I.*)

ELECTED		
1902	Rt. Hon. William Humble Earl of Dudley, Lord Lieutenant-General and General Governor of Ireland. . . .	Vice Regal Lodge, Dublin.
1868 M 1882 H.M.	Grubb, Sir Howard, F.R.S., F.R.A.S., &c.	Rockdale, Orwell-road, Rathgar, Dublin.
1897	Cameron, Sir Chas. A., C.B., M.D., F.R.C.S.I. . . .	51 Pembroke-road, Dublin.
1901	Thrift, Professor W. E., F.T.C.D.	Trinity College, Dublin.

MEMBERS.

(*M.Inst.C.E.I.*)

1901	Allanson-Winn, Rowland Geo. A., B.A., Cantab.	22 South Frederick-st., Dublin, and Glenbeigh, Killarney.
1892	Alexander, *Professor* Thomas, M.A.I.	39 Trinity College, Dublin.
1898	Allen, Henry	Rehoboth House, South Circular-road, Dublin.
1869 F.L.A. 1875 F.L.M.	Apjohn, James Henry M.A., M. Inst. C.E. (*F.L.M.*)	17 Victoria-street, Westminster, London, S.W.
1880	Armstrong, George Allman .	Timoleague and Courtmacsherry Light Ry., Bandon, Co. Cork.
1877	Aspinall, John Audley Frederick, M. Inst. C.E. (*L.M.*, *Past President*)	Gledhill, Mossley Hill Drive, Sefton Park, Liverpool.
1903	Atock, Thomas, B.A. . .	25 Cabra-road, Dublin.
1880	Backhouse, Marmaduke, M.A.I. (*Honorary Secretary*)	9 Harcourt-terrace, Dublin.

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ELECTED		
1902	Bain, Andrew (Major, R.E.) (*L.M.*)	Commissioner of Civil Police, Northern Nigeria, West Africa.
1896	Barnard, Albert William . .	Coolyhane House, Macroom, Co. Cork.
1896	Barnes, Robert Stephenson .	Tatestown, Navan, Co. Meath.
1876 A 1879 M	Barnes, John Frederick Evelyn, C.M.G., M. Inst. C.E. (*F.L.M.*)	Chief Engineer, P. W. D., Natal, South Africa.
1874 A 1880 M	Barrington, Edward . .	3514 N. St., N.W., Wash., D.C., U.S.A.
1865	Beatty, John	India.
1892	Bergin, Francis, B.E. . .	Beech Grove, Kildare.
1899	Bergin, John Philip . . .	County Surveyor's Offices, 11 Rutland-square, Dublin.
1890	Berry, Joseph . .	Town Hall, Kingstown, Co. Dublin.
1883	Birch, Edward Robert, Assoc. M. Inst. C.E. . .	Millview, Bridgetown, Co. Donegal.
1900	Brett, Henry Charles . .	19 Wellington road, Dublin.
1874	Brett, John H. (*L.M.*) . .	Co. Surveyor, Antrim; Belfast.
1895	Buckley, Michl. J. . . .	26 Bessboro'-terrace, North Circular-road, Dublin.
1904	Calwell, Robert Inkerman, B.E.,	21 Arthur-street, Belfast.
1876 A 1883 M	Chappell, Henry . .	The Grove, Newtownards, Co. Down.
1895	Clarke, Eugene O'Neill . .	County Surveyor, Leitrim; Carrick-on-Shannon.
1865	Clark, George R. . . .	
1903	Clarke, Henry Wray, M.A. .	Bay View, Larne Harbour, Co. Antrim.
1870 A 1882 M	Cochrane, Robert, I. S. O., M. R. I. A., F. S. A., F.R.I.B.A. (*President*)	Board of Works, Dublin, and 17 Highfield-road, Rathgar.
1888	Coey, Robert	St. John's, Island Bridge, Dublin.

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ELECTED		
1890	Coffee, Francis R. . . .	2 Eaton-terrace, Tramore.
1902	Collen, Wm., M. Inst. C.E. .	County Surveyor, Dublin, 70 Upper Leeson-street; Dublin.
1886	Comber, Patrick Forstall . . M. Inst. C.E., F.S.I.	19 Lower Leeson-street, Dublin.
1865	Cooke, Theodore, M.A., M.A.I., LL.D., C.I.E., F.G.S., F.L.S. (*F.L.M.*)	Portswood, Kew Gardens, Surrey.
1900	Cowan, Peter Chalmers, M. Inst. C.E.	Local Government Board, Dublin.
1860	Crawford, Robt., M.E., M. Inst. C.E.	Stonewold, Ballyshannon, Co. Donegal.
1883	Creery, Leslie, B.A.I . .	Lisnalurg, Shankill, Co. Dublin.
1892	Cusack, Henry Edward . .	M. G. W. Ry. Works, Broadstone, Dublin.
1902	Davis, Charles Henry (*F.L.M*).	25 Broad-street, New York.
1884 A 1899 M	De Burgh, Ernest Macartney	Union Bank of Australia, Sydney, N.S.W.
1900	Dick, Fred. J., M. Inst. C.E. (*Member of Council*)	Board of Works, Dublin.
1863	Dillon, James, M. Inst. C.E., (*Past President*)	36 Dawson-street, and Stratford House, Glenageary, Co. Dublin.
1862	Dodd, George (*F.L.M.*)	
1888	Doyle, Patrick (*F.L.M.*), . M.R.I.A., F.R.S.	19 Lall Bazar, Calcutta.
1878	Duffin, William Edmund L'Estrange	County Surveyor, Waterford Larkfield, Waterford.
1898	Fallon, Bernard N. . . .	Netterville Lodge, Toomard, Ballinasloe.
1873 A 1899 M	Ferguson, William, B.E., M.A., M. Inst. C.E.	Harbour Board, Wellington, New Zealand.
1894	Fletcher, Francis Dudley . .	Shannon Office, Board of Works, Limerick.
1900	Fortescue, Matthew, . .	57 Grosvenor-road, Rathgar.

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ELECTED		
1903	Gallagher, Stephen Gerald .	County Surveyor, Wicklow; Corballis Castle, Rathdrum, County Wicklow.
1875	Geoghegan, Samuel . . (*Member of Council*)	The Grove, Killiney, County Dublin.
1888 A 1893 M	Gilcriest, William Fawcette	Wine-street, Sligo.
1877	Glover, Edward, M.A., B.E., M. Inst. C.E., F.R.I.B.A. (*Past President*)	County Surveyor, Kildare; Courthouse, Naas.
1887 A 1892 M	Going, Shirley Russell (*L.M.*)	17 Nassau-street, Dublin, and 35 Sandycove-road, Kingstown, Co. Dublin.
1895	Gray, George David . .	36 Edenvale-road, Ranelagh, Co. Dublin.
1887	Greenhill, William . . .	Great Northern Railway, Dundalk.
1903	Griffith, Dudley Perceval . . (*F.L.M.*)	Chinese Mining and Engineering Co., Tongshan, North China.
1871	Griffith, John Purser, M. Inst. C.E. (*Past President*)	Rathmines Castle, Rathmines, and Port and Docks Office, East-wall, Dublin.
1886 A 1899 A.M. 1902 M	Hade, Wm. Patrick .	Dublin-street, Carlow.
1898	Hargrave, Joshua Harrison, B.A., B.E. .	Great Northern Railway, Amiens-street, Dublin.
1898 A 1902 M	Harriss, George Marshall .	Barrow House, Carlow.
1875	Harty, Spencer . . . (*Past President*)	5 Trevelyan-terrace, Rathgar, and Engineer's Office, City Hall, Dublin.
1896	Haycroft, James Isaac (*F.L.M.*)	Fontenoy, Ocean-st., Woollahra, Sydney, New Sth. Wales.
1872	Heenan, Robert Henry, M. Inst. C.E.	Harbour Works, Cape Town.
1887	Henderson, Ernest . . .	Canadian Pacific Railway, Smithfalls, Ontario, Canada.

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ELECTED		
1902	Hickson, George, A.E., B.A.I.	25 Denny-street, Tralee.
1895	Hill, William Henry, junr. .	8 York-terrace, Cork.
1903	Holmes, Geo. C. V. . .	Chairman, Board of Works; Dornden, Booterstown, Co. Dublin.
1901	Hope, John Basil . . .	M.G.W.Ry. (Loco. Engineers' Dept.), Broadstone, Dublin.
1904	Hopkirk, Fras. Geo. .	Midland Ry. Northern Counties Committee, Belfast.
1897	Hurtzig, Arthur Cameron, M.Inst. C.E.	2 Queen Square-place, Westminster, London, S.W.
1882	Ivatt, Henry Alfred, M. Inst. C.E. (*Past Vice-President*)	Gt. Northern Ry., Doncaster.
1893	Johnston, George Leopold .	6 Victoria-street, Armagh.
1901	Jolly, James	8 Hilton-avenue, Urmston, Manchester.
1877	Joyce, Arthur Edward . .	County Surveyor, Westmeath; Ballinagore, Co. Westmeath.
1896	Keating, Wm. Johnson, B.E. .	28 York-road, Rathmines, Dublin.
1887	Kernaghan, William . . .	11 Rutland-square, Dublin.
1902	Kirwan, Robert Joseph, B.A., B.E.	Gardenfield, Tuam.
1901	Latham, Frank . . .	Municipal Buildings, Penzance.
1883	Latimer, John	12 Denny street, Tralee.
1898	Leahy, James D. . . .	Newcastle West, Co. Limerick.
1889	Leask, Robert H. . . .	37 College-green, Dublin.
1901	Lilly, Walter Elsworthy . .	39 Trinity College, Dublin.
1856	Lyons, M. E. (*F.L.M.*) . .	
1884	Manning, William . .	Cookstown, Kells, Co. Meath.

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ELECTED		
1896	Martin, Frank V. (*L.M.*) .	82 North Wall, Dublin.
1898	Maunsell, Richard Edward Lloyd .	Mount Vernon, Inchicore, Dublin.
1884	Maxwell, John Francis, M.A. .	
1904	M'Carthy, Patrick Harnett, B.A. B.A.I.	32 Bachelors'-walk, Dublin.
1860	M'Donnell, Alexander, M. Inst. C.E. (*Past President*)	Rydens, Hersham-road, Walton-on-Thames.
1880	M'Donald, Donald . . .	Curran, Larne Harbour, Co. Antrim.
1904	MacFarlane, Robert Melbourne (*F.L.M.*)	Alibag, Ratnagiri and Kolaba District, Bombay Presidency, India.
1882 A 1892 M	M'Mullen, James F. . .	30 South Mall, Cork.
1882	Metge, Peter Ponsonby . .	Creggan, Athlone.
1877	Mills, William Hemingway, M. Inst. C.E. (*Past President*) .	Nurney, Glenageary, and Great Northern Railway, Dublin.
1901	Montgomery, Henry Bevan Slator, L.C.E., T.C.D.	5 Elgin-road, Dublin.
1869 A 1874 M	Moore, Joseph Henry, M.A.I., T.C.D. (*Member of Council*)	County Surveyor, Meath; 63 Eccles-street, Dublin.
1900	Moore, William P. . . .	11 Herbert-road, Sandymount, and Port and Docks Office, East Wall, Dublin.
1879 A 1882 M	Morony, Henry Vereker Lloyd, B.E., Assoc. M. Inst. C.E.	Harbour Commissioners' Office, Limerick.
1866	Morris, Thomas B., M. Inst. C.E.	Messrs. King, King & Co., Bombay.
1888	Morris, William Henry . .	Belfast and Co. Down Ry., Belfast.
1881	Moynan, John Ousley, M.A. .	Co. Surveyor, North Tipperary, Nenagh.
1888	Moynan, Joseph, B.E., Assoc. M. Inst. C.E.	Dundas Shire, Hamilton, Victoria, Australia.
1883	Mulvany, Christopher, M.A., B.E., M. Inst. C.E. .	County Surveyor, Roscommon; Athlone.
1882	Myles, Thomas Joseph, B.A., M. Inst. C.E. .	Engineer's House, M.G.W. Ry., Athlone.

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ELECTED		
1903	O'Brien, Edward S.	Westown House, Wexford.
1896	O'Neill, William Purcell	Highfield, N.C. Road, Dublin, and Engineer's Office, M. G. W. Railway.
1887 A 1899 M	Ormsby, Charles Croasdaile	District Engineer's Office, M. G. W. Ry., Galway.
1869 A 1876 M	Ormsby, Robert Daly	St. Kevin's, Dalkey.
1892 A 1898 M	O'Sullivan, John G., Assoc. M. Inst. C.E.	2 Charleville-terrace, N.C.R., Dublin.
1901 A.M. 1903 M.	O'Sullivan, Patrick F.	Tolka View, Richmond-road, Fairview, Dublin.
1903	Ormsby, Michael Thos. Morley	95 Abbeville-road, Clapham, London, S.W.
1888	Parry, William Kaye, M.A., B.E., M. Inst. C.E., F.R.I.B.A.	63 Dawson-street, Dublin, and 6 Charlemont-terrace, Kingstown.
1898	Parshall, Horace F.	Salisbury House, London Wall, London, E.C.
1891 A 1891 M	Payne, Sinclair William	Upton House, Co. Cork.
1895	Perrott, William George, B.A., B.E., Assoc. M. Inst. C.E.	Gracefield House, Blackrock, Co. Dublin.
1874	Pigot, Thomas F. (*Past President*)	14 Fitzwilliam-place, Dublin.
1903	Pilkington, Thomas Henry	Glenard, Clare Castle.
1897	Porter, Samuel	27 Beresford-road, Oxton, Cheshire.
1897	Price, Alfred Dickinson, M.A. Ing., M. Inst. C.E.	3 Fortfield-villas, Palmerston-park, and Local Government Board, Dublin.
1896	Price, James, M. Inst. C.E.	Engineer, Harbour Commissioners, Cork.
1865	Price, W. H., M. Inst. C.E.	Southsea.
1883 A. 1901 M.	Purcell, Marmaduke F.	12 Pembroke-road, Dublin.
1900 A.M. 1903 M.	Quigley, John	Holmdale, Seafield-road, Clontarf, Dublin.

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ELECTED		
1874 A 1893 M	Ross, George Murray, M.A., B.E. (*Member of Council*)	63 Dawson-street, Dublin.
1884	Ross, William, B.A.I., T.C.D. (*Vice-President and Hon. Treas.*)	66 North Wall, Dublin, and Summerfield, Dalkey.
1893	Rowe, James Thomas . .	25 St. Andrew's-terrace, North Circular-road, Dublin.
1896	Ruddle, Mark, M.I.E.E., (*Member of Council*)	7 Lansdowne-terrace, Shelbourne-road, Dublin.
1902	Ryan, Hardinge Stanley, B.A.I.	61 Main-street, Tipperary.
1896	Ryan, John Henry, M.A., M. Inst. C.E. (*Past President*)	22 Nassau-street, Dublin.
1882 A 1887 M	Shannon, Samuel James, B.E.	Claremont, Meath-road, Bray.
1881	Shaw, Prosser Austin Haynes, L.C.E., T.C.D. (*Member of Council*)	21 Clarinda-park, Kingstown, and St. James' Gate Brewery, Dublin.
1896	Smith, John Chaloner . .	Engineer's Office, Board of Works, Dublin.
1861	Smyth, John, M.A., F.C.S. .	Milltown, near Banbridge.
1881 A 1894 M	Smyth, Richard O'Brien . (*Member of Council*)	2 Kenilworth-square, Rathgar, and Local Government Board, Dublin.
1882	Stewart, Abraham M'Causland, B.E.	Victoria Chambers, Strand, Derry.
1904	Stewart, Percy Herbert . .	94 Leinster-road, Rathmines, Dublin.
1902	Stirling, J. A. Maxwell (*F.L.M.*), A. M. I. M. E., M. S. A., M. Archts. Assocn.	Resident Engineer, Great Indian Peninsular Railway, Agra—Delhi Line, Agra, India.
1857	Stoney, Bindon Blood, F.R.S., LL.D., M.R.I.A., M. Inst. C.E. (*L.M.*, *Past President*)	14 Elgin-road, Dublin.
1868	Stoney, Edward Waller, M.E., M. Inst. C.E. (*F.L.M.*)	Chief Engineer, Madras Railway, Royapuram, Madras.
1873	Stoney, Robert Vesey (*L.M.*) .	Rosturk Castle, Co. Mayo.
1872	Stoney, Thomas Butler (*F.L.M.*)	Oakfield, Raphoe, Co. Donegal.
1880	Spence, William . . .	107 Cork-street, Dublin.
1891	Sutter, Charles H. N. . .	42 Dame-street, Dublin.

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ELECTED		
1882	Thomson, Frank William, B.E.	
1901	Towle, John William . .	Moscow Mansions, Cromwell-road, South Kensington, London, S.W.
1860	Tuthill, Robert Reeves . .	
1893	Vereker, Henry Robert, F.S.I. .	Shevdilla, Westport, Co. Mayo.
1903	Wakeman, William James Perrin	117 Cavehill-road, Belfast, and Gt. Northern Railway (I.), Belfast.
1865	Waller, George Arthur, M.A. (*L.M.*)	Cangort Lodge, Hobart, Tasmania.
1862	Walpole, Thomas . . .	Windsor Lodge, Seafield-av., Monkstown, Co. Dublin.
1875	White, Henry Vincent . .	County Surveyor, Queen's Co., Maryborough.
1874	Willson, Frederick Richard Thomas, B.E.	Lake View, Kilrea, Co. Londonderry.
1897	Wilson, John George . .	Kylasse, Chalvey Park, Slough, Bucks.
1876 A 1880 M	Wise, Berkeley Deane, M.Inst. C.E. (*Vice-President*)	Silverstream House, Greenisland, and Midland Railway, Northern Counties Committee, Belfast.
1871	Wright, John Arthur (*F.L.M.*)	Cadiz Water Works, Sto. Cristo 4, Cadiz.

ASSOCIATE MEMBERS.

(*Assoc. M. Inst. C.E.I.*)

1897 A 1899 A.M.	Acton, John Henry .	Civil Eng. Staff, East Indian Railway, Calcutta.
1895 A 1899 A.M.	Ashworth, Charles Herbert	42 Dame-street, Dublin.
1879 A 1899 A.M.	Barnes, Robert Samuel Wemyss, Assoc. M. Inst. C.E.	Durban Club, Natal, and Whitehall Club, London, S.W.

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ELECTED		
1900	Barnes, Robert Stephenson, junr.	Tatestown, Navan.
1888 A 1899 A.M.	Barry, William Fitzgerald, Assoc. M. Inst. C.E.	County Surveyor, Monaghan; Town View, Monaghan.
1900	Blake, John . . .	Ballyglunin Park, Co. Galway.
1903	Blanchard, James Francis	11 Wellesley-terrace, Southern-road, Cork.
1902	Browne, Henry . .	1 Cumberland-terrace, Birr.
1902	Butler, Rudolph M. .	12 Dawson-street, Dublin.
1901	Byrne, John Joseph .	Engineer's Office, Grand Canal, Dublin.
1903	Bretland, Arthur White .	Bramscote, Craigavad, Co. Down.
1901	Colaco, Alinsio Leonard (*F.L.A.M.*)	9 Hornby-road, Fort, Bombay.
1901	Crawcour, Chas. Edward Stuart	Glen View, Howth, Co. Dublin.
1904	Crofts, Freeman Wills .	Midland Railway Northern Counties Committee, Engineer's Office, Coleraine.
1896 A 1904 A.M.	Cuttriss, Alfred W. M.	R. E. Dept., Buncrana, Co. Donegal.
1896 A 1899 A.M.	Delaney, James . .	County Surveyor, King's Co. Tullamore.
1898 A 1899 A.M.	Dillon, J. T. Trevor .	R. E. Office, Armagh.
1900	Douglas, Charles K. .	Rathmolyon, Enfield, Co. Meath.
1896 A 1899 A.M.	Evans, Richard . .	53 South Mall, Cork.
1896 A 1899 A.M.	Fitzgerald, Cecil Henry (*F.L.A.M.*)	Assistant City Engineer, Georgetown, Demerara, British Guiana.
1903	Fleming, John Joseph .	Mount View, John's Hill, Waterford.
1895 A 1899 A.M.	Forsyth, Thomas . .	4 Florina Villas, Terenure Park, Dublin.

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ELECTED		
1887 A 1899 A.M.	Gaffney, Francis Sebastian, Assoc. M. Inst. C.E.	Colonial Engineer's Office, Singapore, S.S.
1902	Galbraith, A. de Rohan .	Town Hall, Portsmouth.
1903	Galbraith, Fred. Victor .	Gold Coast Government Railways, Sekondi, W. Africa.
1903	Grant, Lawford Stanley Foster	Snowdon, Fishponds, near Bristol.
1904	Griffith, John William, M.A., B.A.I.	Greenane, Temple-road, Rathmines, Dublin.
1898 A 1902 A.M.	Hargrave, Wm. Harrison	R.E. Office, Curragh Camp.
1896 A 1901 A.M.	Harris, Herbert T. . .	30 Parliament-street, Dublin.
1904	Hayes, James Gordon Lennox, M.S.E., M.San. Inst.	Avenue Chambers, Belfast.
1902	Hughes, R. Lloyd . .	35 St. Mary's-road, Dublin.
1900	Hurley, Hugh Stanislaus .	
1902	Inglis, John Joseph .	Town Hall, Naas.
1896 A 1899 A.M.	Jackson, James Thomas .	13 Kimmage-road, Harold's Cross, Dublin.
1904	Jephson, George Hastings	Court House, Waterford.
1903	Joynt, George Lawrence	Town Surveyor's Office, Ballina, Co. Mayo.
1902	Kerr, Henry Forrest .	39 Clarinda-park, West, Kingstown.
1902	Krishna, Nil, Sen. . . (*F.L.A.M.*)	227/33 Upper Circular-road, Shambazar, Calcutta.
1901	Leask, Henry Norman .	Englefield, Hartington-road, Chorlton-cum-Hardy, Manchester.
1903	Maxwell, Alexander .	Harbour Works, Ardmore, Youghal.
1904	M'Alery, Joseph Richard Pike	Marino, Whitehead, Co. Antrim

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ELECTED		
1902	Magill, Joseph Ponsonby .	Beaufort. Co. Kerry.
1903	M'Candliss, John C. .	10 Downshire-road, Newry.
1890 A 1899 A.M.	MacGarvey, Howard .	Lombard-street Works, Dublin.
1903	M'Grath, Joseph P. .	100 Leinster-road, Rathmines.
1894 A 1899 A.M.	Moore, George Tighe .	184 Gt. Brunswick-street, Dublin.
1903	Nicolls, Geo. Alex. .	Cahirciveen, Co. Kerry.
1901	O'Connell, James . .	Altmuish Cottage, Kilmainham Wood, Co. Meath.
1903	O'Neill, Thomas J. . .	19 Crumlin-road, Belfast.
1902	Pansing, John . . .	Church-hill, Wicklow.
1897 A 1900 A.M.	Richardson, Thos. Henry	c/o Grindley and Groom, Calcutta.
1887 A 1902 A.M.	Rochford, John . .	4 Clarinda-park, West, Kingstown, and Board of Irish Lights.
1904	Rockett, Joseph Alexander	33 Parkgate-street, Dublin.
1903	Roe, George Deane .	3 Lower Hatch-street. Dublin.
1901	Sheehy, Bryan Edward Fitzgerald.	57 George-street, Limerick.
1904	Sparrow, Wm. Warburton Knox (*F.L.A.M.*)	c/o Chief Engineer, Cape Government Railways, Cape Town.
1893 A 1899 A.M.	Spence, Arthur Wm. .	11 Brighton-avenue, Rathgar, Dublin.
1902	Stewart, Pakenham Thos.	19 Malone-avenue, Belfast.
1902	Taylor, Henry Thomas .	11 Newton-road, Hoylake, Cheshire.
1901	Travers, Frank V. J. .	Butlerstown House, Timoleague, Co. Cork.
1903	Tomlinson, Thomas . B.A.I., T.C.D., M.I.E.E.	3 Quinsboro'-terrace, Bray.

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ELECTED		
1890 A 1899 A.M.	Warren, George Gates .	
1902	Whieldon, Arthur Wilkinson	Berkeley-villa, Sutton, Co. Dublin.
1903	Wise, Jas. Berkeley .	Cork, Bandon, and South Coast Railway, Bandon, Co. Cork.

ASSOCIATES.

(*Assoc. Inst. C.E.I.*)

1896	Allen, William Henry . .	The Terrace, Ennis.
1884	Anderson, Wm. (*Member of Council*)	9 Upper Sackville-street, and Glenavon, Merrion-road, Dublin.
1896	Benson, William Arthur Sanders	Lalghur, Carlton-road, Ealing, London, W.
1895	Bingham, Charles H. . .	Messrs. Tedcastle, M'Cormick, & Co., Dublin.
1898	Bolton, Samuel H. (*F.L.A.*) .	2 Hume-street, Dublin.
*1902	Browne, George . . .	46 Rathgar-avenue, Co. Dublin.
*1902	Callaghan, Alfred J., LL.D. .	11 Northumberland-road, Dublin.
*1901	Clayton, Henry F. . . .	41 Fleet-street, Dublin.
*1903	Cornwall, Alfred M. . .	Thomasfort, Ballygar, Co. Roscommon.
1889	Deane, Louis E. H. . . .	Local Government Board, Dublin.
1896	Espinasse, James . . .	c/o Standard Bank of South Africa, Cape Town.
1883	Evans, James	20 St. Peter's Terrace, Phibsborough, Dublin.
1874	Falkiner, Nathaniel L. . .	Port Chalmers, New Zealand.
1881	Fleming, Henry . . .	Chicago, U.S.A.

* Marked thus are Non-Corporate Associates.

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ELECTED		
1885	Gill, Robert Paul . . .	30 Castle-street, Nenagh.
1895	Gilcriest, John Fawcette .	Wine-street, Sligo.
*1901	Gordon, C. W. . . .	53 Northumberland-road, Dublin.
1879	Gray, William Armroyde . .	New York.
1896	Hewitt, Wm. Tyrrell O. B., F.R.G.S. .	West Indian Club, Howard Hotel, Norfolk-st., London, S.W.
1897	Higginbotham, Fred. Wm. .	9 Lr. Sackville-street, Dublin.
1896	Kelly, Cecil Fletcher . .	Johnstown House, Athlone.
1895	Lamon, Thomas W. . .	Newtownards, Co. Down.
1885	Maguire, William Robert .	Tower Hill, Dalkey, and 10 Dawson-street, Dublin.
1867	Martin, Charles E. (*L.A.*) .	82 North Wall, Dublin.
1888	Martin, John E., B.A., T.C.D. (*L.A.*) .	82 North Wall, Dublin.
1890	Martin, Thomas P. (*L.A.*) .	82 North Wall, Dublin.
*1903	M'Ardle, Arthur Andrew .	Talbot Villa, Sydenham, Belfast.
1898	M'Cann, Walter . . .	Town Surveyor, Drogheda.
1895	M'Caw, George Tyrrell . .	
1893	M'Kenzie, Colin Douglas . .	Burton Ville, Southampton-street, Farnboro', Hants.
*1903	Mooney, Frederick Morgan .	118 Pembroke-road, Dublin.
1898	Morris, Ernest Horatio . .	43 Dame-street, Dublin.
1892	Mulville, Michael Walsh . .	Court-road, Listowel, Kerry.
1881	Murphy, William M. . .	Dartry, Rathmines, Dublin.
*1900	Nolan, Edward P. . . .	The Quoile, Downpatrick.
1897	O'Kelly, W. H. . . .	Sion House, Glenageary, Co. Dublin.
1893	Owen, Charles Austin . .	29 Molesworth-street, Dublin.

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ELECTED		
*1903	Palmer, J. E.	Rose Lawn, Ballybrack, Co. Dublin.
1895	Phillipson, Burton R.	Calgarth, Dalkey, Co. Dublin.
1888	Power, James Talbot, D.L. (*L.A.*)	Leopardstown Park, Co. Dublin.
*1903	Quirk, Charles James	Prospect, Milltown, Co. Dublin.
1895	Reinhardt, John	Qui-si-sano, Newtown-a Blackrock, Co. Dublin.
*1904	Rutherford, William Reid	Main-street, Ballibay, Monaghan.
1892	Stuart, William Henry	Rockfield, Streamstown, Westmeath.
*1901	Tatlow, Joseph	M. G. W. Ry., Broadston Dublin.
1887	Tresilian, Richard S.	9 Sackville-street, Upper, Cumnor, Eglinton-r Donnybrook, Co. Dubli
*1902	Waring, Henry	Shanagarry, Milltown, Dublin.
1887	Watson, Charles W.	Hollywood House, Princes Melbourne, Australia.
1867	Woodward, Richard Caleb	Brisbane, Queensland.
1881	Worthington, Robert	40 Dame-street, Dublin.

* Marked thus are Non-Corporate Associates.

NOTE—*L.M., Life Member; F.L.M., Foreign Life Member; L.A.M., Life Associa Member; F.L.A.M., Foreign Life Associate Member; L.A., Life Associate F.L.A., Foreign Life Associate.*

STUDENTS.

Seigne, Richard Barter	Old Bank House, Cahir.
Smith, John	6 Grace-park Gardens, Drumcondra, Dublin.

Printed by JOHN FALCONER, 53 Upper Sackville-street, Dublin.

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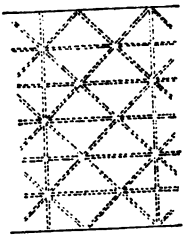


Fig. 17.

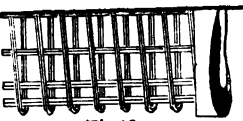
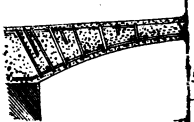


Fig. 42.

Fig.

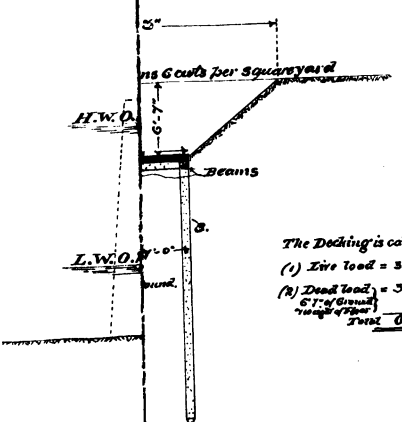


ystem.

Fig. 45.

Fig. 46.

Quay Wall.



The Decking is calculated to carry:—

(1) Live load = 3 ltm 6 cwts per sq. yd

(2) Dead load = 3 " 8½ " " " "
6'7" of Ground
" weight of Floor
Total 6 " 14½ " " "

Scale $\frac{1}{100}$th.

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